CONTAMINACION POR ARSENICO Y METALES TRAZA EN SUELOS INUNDABLES DE BANGLADESH

(Arsenic and Trace Metal Pollution in Floodplain Soil of Bangladesh)

DEWAN ALI AHSAN

TESIS DOCTORAL

- Cádiz, 2008 -

TESIS DOCTORAL

CONTAMINACION POR ARSENICO Y METALES TRAZA EN SUELOS INUNDABLES DE BANGLADESH

Dewan Ali Ahsan

(Página reservada para catalogación bibliográfica)

UNIVERSIDAD DE CÁDIZ

FACULTAD DE CIENCIAS DEL MAR Y AMBIENTALES

CONTAMINACION POR ARSENICO Y METALES TRAZA EN SUELOS INUNDABLES DE BANGLADESH

Dewan Ali Ahsan

Cádiz, 2008

UCA
Universidad de Cádiz

Esta Tesis Doctoral ha sido realizada en el Departamento de Química-Física de la Facultad de Ciencias del Mar y Ambientales de la Universidad de Cádiz y en el Instituto de Ciencias Marinas de Andalucía (CSIC), como parte de las actividades de la Cátedra UNESCO/UNITWIN/WiCop. El trabajo que se resume en esta memoria ha sido financiado principalmente por los siguientes proyectos. Desarrollo y Mejora del análisis integrado para la evaluación de la calidad de sedimentos litorales, incluidos los materiales de dragado portuario (CTM2005-07282-C03-C01/TECNO) y Análisis y modelado del comportamiento de lixiviación en condiciones de equilibrio de la movilidad de metales de sedimentos marinos encontacto con fugas de CO2 de procesos CS-SSGS (CTM2008-06344-C03-03/TECNO) financiados por el Ministerio de Ciencia e Innovación Plan Nacional. El trabajo desarrollado en la tesis forma parte de las líneas de investigación del doctorado con mención de calidad del mencionado ministerio titulado ‘Gestión de Aguas y Costa’.

Memoria presentada para optar al titulo de

Doctor en Gestión de Agua y Costas

Dewan Ali Ahsan

D. T. ANGEL DEL VALLS CASILLAS, Profesor Titular del Departamento de Quimica-Física de la Universidad de Cádiz, D. JULIÁN BLASCO, Investigador Científico del CSIC, como sus directores

HACEN CONSTAR:

Que esta Memoria, titulada “Contaminación por arsénico y metales traza en suelos inundables de Bangladesh”, presentada por D. Dewan Ali Ahsan, resume su trabajo de Tesis Doctoral y, considerando que reúne todos los requisitos legales, autorizan su presentación y defensa para optar al grado de Doctor Gestión Agua y Costas por la Universidad de Cádiz.

Cádiz, Noviembre de 2008

Dr. T. Angel Del Valls   Dr. Julián Blasco

Acknowledgements

I would like to express my heartiest gratitude to Professor ANGEL DELVALLS CASILLAS and Dr. JULIAN BLASCO for supervising the project. They provide guidance, continuous support and constructive criticisms throughout the study period. I am so grateful to find them as my superviors.

Special thanks to UNESCON/UNITWIN/WiCop to provide part of fund of the research

I would like to express my gratitude to the Ministry of Education and Science in Spain who certify the PhD progarme (Gestión de Aguas y Costas, MCD2006-00288)

Special thanks to all representatives of respondents NGOs to spent their valuable time with the author and kind cooperation.

The author would also like express thanks to his wife, Mashura Mizan for her continued encouragement to finish the work

At last very special thanks to European Union and to provide financial support for the some part of study from the ERASMUS MUNDUS scholarship programme

Índice de contenidos

CHAPTER 1

(CAPÍTULO 1)

INTRODUCTION, STUDY AREA, HYPOTHESIS, OBJECTIVES AND STRUCTURE OF THE THESIS

(INTRODUCCIÓN, ZONAS DE ESTUDIO, HIPÓTESIS, OBJETIVOS Y ESTRUCTURA DE LA TESIS DOCTORAL)

1. 1 INTRODUCTION

Bangladesh is a developing country of South–East Asia. The total area of the country is 147,000 square kilometer and population size is near about 140 million. It is bounded by India on East, West and North side. On the south, it is covered by the Bay of Bengal (Figure 1) .The whole country is divided into 64 districts and these are divided into a number of upazilas (sub-district). Each upazila then consists of several unions and each union of several villages. The country experiences a heavy rainfall during the Monsoon, generally more than 1500 mm annually. Very little of the country is more than 12 m (40 feet) above sea level and in a normal monsoon season one-third of its cultivated land is flooded (Monan, 1995).About 82% of the population live in rural areas. More than 80% of the population depends on agriculture for its livelihood. The agricultural sector employs about 90% of rural males as well as 80% of rural females of the country.

Groundwater is the main source of drinking water in most of the developed and developing countries (Table 1). It is estimated that approximately one third of the world's population use groundwater for drinking (UNEP, 1999). In 1990s, several studies detected naturally occurring As in groundwater (due to anthropogenic and non-anthropogenic activities) in the USA, Argentina, Taiwan, China, Hungary, Vietnam, and the Ganges Plain (Smedley and Kinniburgh, 2002, Anwar, et al., 2003; Roychowdhury, et al., 2002; Chakraborti, et al., 2001; Smith, et al., 1998; Chowdhury et al., 2000) However, aarsenic contaminating groundwater in Bangladesh is one of the largest environmental health hazards in the world. It is also one of the major problems of West Bengal India. More than 70 million people are at risk. About 4 million cases of arsenic related illness in the country at present. WHO water guideline for As is 0.01 mgL^{-1}(WHO, 1993). However, many countries, particularly developing ones, still use the 50 $\mu gL^{-1}$of As standard (Table 2) because of lack of adequate testing facilities for lower As concentrations (Narcise, et al., 2005).

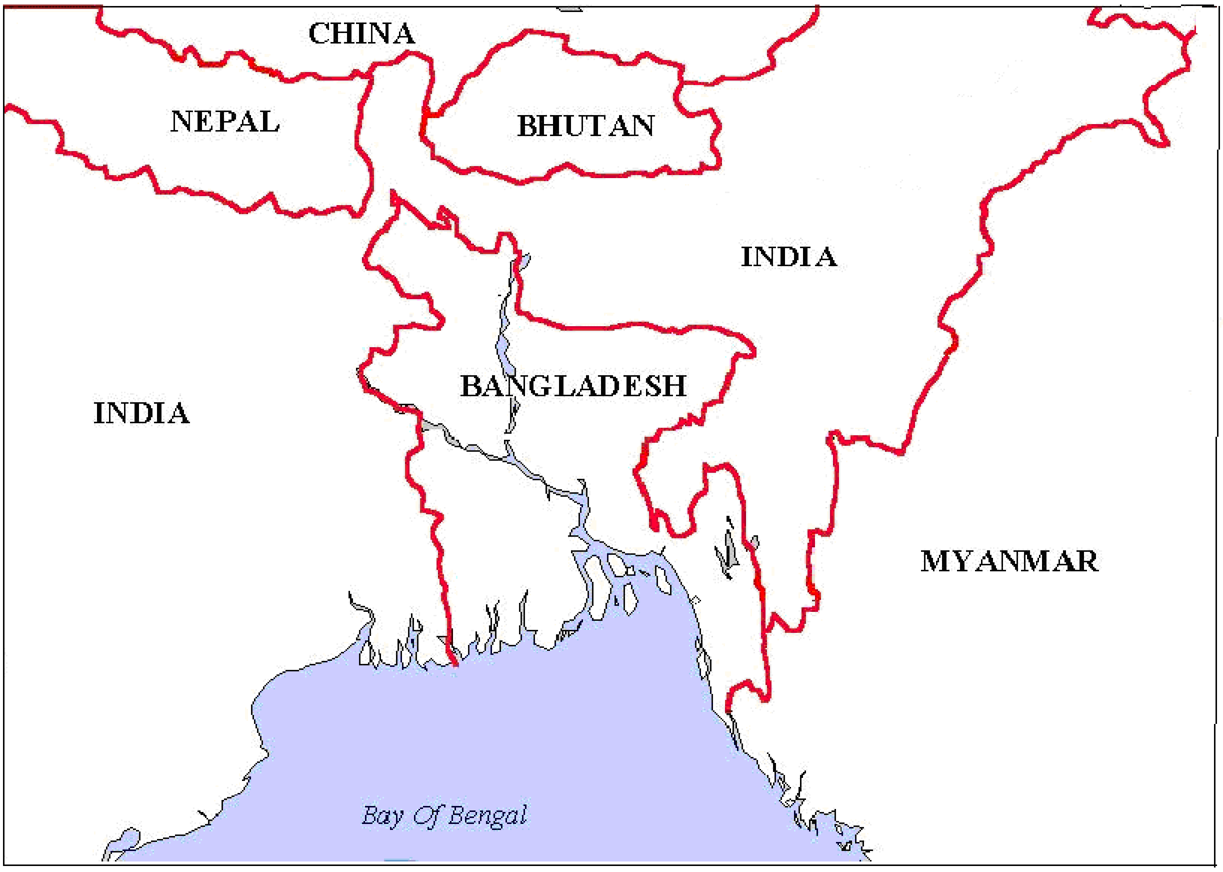


Figure 1: Map of Bengal delta Plain (redrawn after, Reliefweb, 2008)

At present, 90% of Bangladeshi depends on ground water for drinking, because much of surface water of Bangladesh is microbially unsafe to drink. Until the 1960´s the main source of drinking water was surface water, but severe problems with water-borne diseases such as cholera were then present. To solve this, the government, with assistance from UNICEF, WHO and many NGOs, drilled several million groundwater wells (Ravenscroft, 2003). Besides domestic use, huge quantities of water from shallow aquifer are also used for irrigation during the dry season. Unfortunately, vast area of Bangladesh's groundwater naturally contaminated with arsenic (As) concentrations above the World Health Organization (WHO) drinking water guideline of 0.01 mg/L (WHO 1993, BGS and DPHE, 2001; Smedley, 2003, Anawara et al., 2002). However, the source of As Bengal delta plain is non-anthropogenic.

Table 1: Proportion of groundwater in drinking water supplies in selected countries (modification of EEA, 1999 and UN /ECE, 1999)

Country	Proportion	Country	Proportion
Austria	99%	Bulgaria	60%
Denmark	98%	Finland	57%
Hungary	95%	France	56%
Portugal	80%	Greece	50%
Switzerland	83%	Italy	80%
UK	28%	Germany	72%
Spain	21%	Norway	13%
Netherlands	68%	Czech Republic	43%
Bangladesh	90%		

Table 2. Drinking water limits and soil threshold values for as (modification of Matschullat, et al., 2000).

Water (µg L^{-1})	WHO*	EU	NL	TVO-D	DVGW	BD
As	10	50	10-60	10	10-30	50
Soil (mg Kg^{-1})	Cal.Ass	EU	NL	KSVO-D	KSVO-D	-
As	500	-	29-55	20	20-130	-

WHO World Health Organization, drinking water guidelines; EU: European Union drinking water guidelines and soil threshold values; NL: Dutch standards for groundwater concentrations and permissible soil concentrations (the first numbers refer to reference values, the second to maximum permissible levels); TVO-D: German drinking water standards; DVGW: German surface water (raw water) guidelines (for ranges see NL); Cal.Ass.: Californian Assessment Manual Standards (threshold value for dangerous total concentrations TTLC); KSVO-D: German threshold values for maximum permissible soil concentrations; D-Test: German threshold values for different soil uses (low= children playground, high= industrial area); BD- Bangladesh.

What is arsenic?

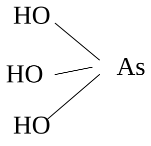
Arsenic (As) is a trace metal which is not the essential element of human body. Arsenic cannot be evaporated by boiling from the water. It can be removed from the water only by filtering column that contains arsenic absorbing materials.

Global production of arsenic is estimated to be 75,000 to 100,000 tons annually, of which the United States produces about 21,000 tons and uses about 44,000 tons; major quantities are imported from Sweden, the world's leading producer (NAS 1977; EPA 1980). Arsenic compounds have been used in medicine since the time of Hippocrates, ca. 400 BC (Woolson 1975).Now-a-days the major uses of arsenic are in the production of herbicides, insecticides, desiccants, wood preservatives, and growth stimulants for plants and animals (Ali, 2003 and Ahmed, 2003).

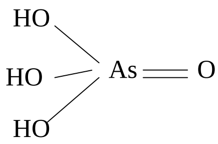
Chemistry of As

The atomic number of As is 33, and it is situated in Group 15 (or VA) of the periodic table. Arsenic ranks twentieth in abundance of elements in the earth's crust, fourteenth in seawater and is the twelfth most abundant element in the human body (Mandal and Suzuki, 2002). The overall arsenic cycle is similar to the phosphate cycle. The regeneration time for arsenic is much slower (Sanders 1980).

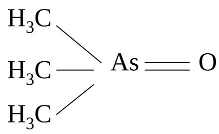
The reduced trivalent form of arsenic As (III), called arsenite, is normally found in anaerobic or reducing groundwater and the oxidized pentavalent form As (V), called arsenate, is found in surface water and aerobic groundwater (Pongratz, 1998; Smith, et al., 1998). In some groundwater, both forms have been found together in the same water source. Arsenate exists in four forms in aqueous solution based on pH: H_3AsO_4, $H_2AsO_4^{-}$, $HAsO_4^{2-}$ and AsO_4^{3-}. Similarly arsenite exists in five forms; $H_4AsO_3^{+}$, H_3AsO_3, $H_2AsO_3^{-}$, $HAsO_3^{2-}$ and AsO_3^{3-} (Smith, et al., 1998).Arsenic is sensitive to mobilisation at pH values typically found in groundwater, i.e. pH 6.5-8.5, and under both oxidising and reducing conditions (Smedley and Kinniburgh, 2002). Chemical structures of some common As compounds are listed in Figure 2 (Goessler and Kuehnelt, 2002).



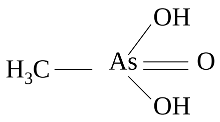
Arsenous acid



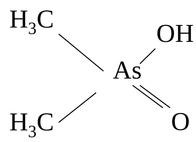
Arsenic acid



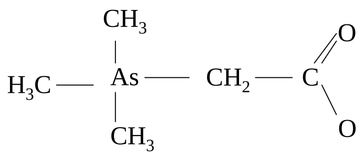
Trimethylarsine oxide



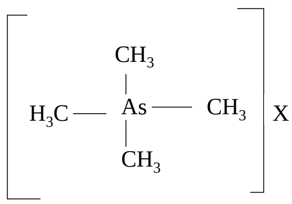
Methylarsonic acid



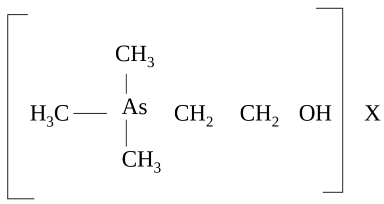
Dimethylarsinic acid



Arsenobetaine



Tetramethylarsonium cation



Arsenocholine

Figure 2: Arsenic compounds commonly detected in the environment (Goessler and Kuehnelt, 2002)

Mobility of As

Arsenic can naturally reside in soil in the form of several types minerals (Table 3). The mobility of As in water and soil depends on several factors like pH, redox conditions, biological activity and adsorption-desorption process (Goh and Lim, 2005). So, the presence of high concentrations of As in groundwater is not generally dependent on the concentration of As in soils. Organic content, soil fractions and oxides of Al, Fe and Mn also affect the amount of As in soil. Several studies have reported the mobilization and attenuation of As in the fine and coarse soil fractions (Lombi, et al., 2000; Cai, et al., 2002. Sadiq, 1997). Sediments with finer texture usually contain more arsenic than sediments with coarser texture. According to Lombi, et al. (2000), the coarse textured soils are likely to yield a higher fraction of readily mobile As, while As in the fine textured soils is relatively immobile, but can be released upon changes in the subsurface geochemical environment. Climate and geomorphic characteristics in an area, such as rainfall, surface runoff, rate of infiltration, and the groundwater level and its fluctuations, also affect the mobility and redistribution of arsenic.

Redox processes

Redox process involves with a large number of chemical reactions by electron transfer. It is well know that when a substance is oxidised, it transfers electrons to another substance, which is then reduced. The point at which a given reaction can take place is determined by the electrical potential difference or redox potential (Eh). Redox potential and pH are the vital factors controlling As speciation (Smedley and Kinniburgh, 2002).

This redox sequence is also influences the behaviours of the important bulk elements specially iron and sulphur, which have very strong binding affinity to arsenic and are principally responsible for the enhanced contamination of arsenic in the environment. The redox process can be enhanced by microorganisms (especially bacteria) as they serve as catalysts in speeding up the chemical reactions.

Table 3: Major arsenic minerals occurring in nature (Smedley and Kinniburgh, 2002)

Mineral	Composition	Occurrence
Native arsenic	As	Hydrothermal veins
Niciolite	NiAs	Vein deposits and norites
Realgar	AsS	Vein deposits, often associated with orpiment, clays and lime stones, also deposits from hot springs.
Orpiment	As_2S_3	Hydrothermal veins, hot springs, volcanic sublimation products.
Cobaltite	CoAsS	High-temperature deposits, metamorphic rocks.
Arsenopyrite	FeAsS	The most abundant As mineral, dominantly in mineral veins.
Tennantite	$(Cu, Fe)_{12}As_4S_{13}$	Hydrothermal veins.
Enargite	Cu_3AsS_4	Hydrothermal veins.
Arsenolite	As_2O_3	Secondary mineral formed by oxidation of arsenopyrite, native arsenic and other As minerals.
Claudetite	As_2O_3	Secondary mineral formed by oxidation of realgar, arsenopyrite and other As minerals.
Scorodite	$FeAsO_4.2H_2O$	Secondary mineral
Annabergite	$(Ni,Co)_3(AsO_4)_2.8H_2O$	Secondary mineral
Hoernesite	$Mg_3(AsO_4)_2.8H_2O$	Secondary mineral, smelter wastes.
Haematilite	$(Mn, Mg)_4Al(AsO_4)(OH)_8$	
Conichalcite	$CaCu(AsO_4)(OH)$	Secondary mineral
Pharmacosiderite	$Fe_3(AsO_4)_2(OH)_3.5H_2O$	Oxidation product of arsenopyrite and other As minerals.

Adsorption/desorption

Mobility of As in natural system also largely depends on adsorption and desorption processes. Both arsenate and arsenite are adsorbed to the surfaces of many different solids including iron, aluminium and manganese oxides, as well as clay minerals. Arsenate is much more strongly adsorbed than arsenite because of its greater negative charge at the same pH (Abedin et al., 2002).

Detection of ground water arsenic in Bangladesh

The arsenic problem was first detected in the northern parts of Bangladesh in the late 1980's following similar problems in West Bengal of India a few years earlier. It is estimated that about 52 of the 64 districts of Bangladesh now affected by arsenic problem (Figure 3). The Department of Public Health Engineering in Bangladesh, British Geological Survey and Mott-MacDonald first conducted the national survey on As concentration in ground water in 1998-99 with the financial support from the UK Department for International Development (DFID). This survey was designed to provide a representative sample of water supplies tested for arsenic across the country to obtain a clear picture of the overall national scale of the arsenic problem (BGS and DPHE, 2001). The survey tested 3,534 tube-wells across the country and covered all 61 plain land Districts.

This survey suggested that arsenic contamination was concentrated in the shallow aquifers of up to 150m (roughly 500 ft) depth, although the highest average contamination was found in the 15-30m (50-100ft) range. The very shallow aquifer of below 15m (50ft) appeared to be largely arsenic free (Rosenboom, 2004). However, recent studies have shown low arsenic levels also in wells deeper than 30-60 m, indicating that the arsenic distribution in groundwater is not only correlated with depth but also with subsurface geology, i.e. age and grain size of sediments.

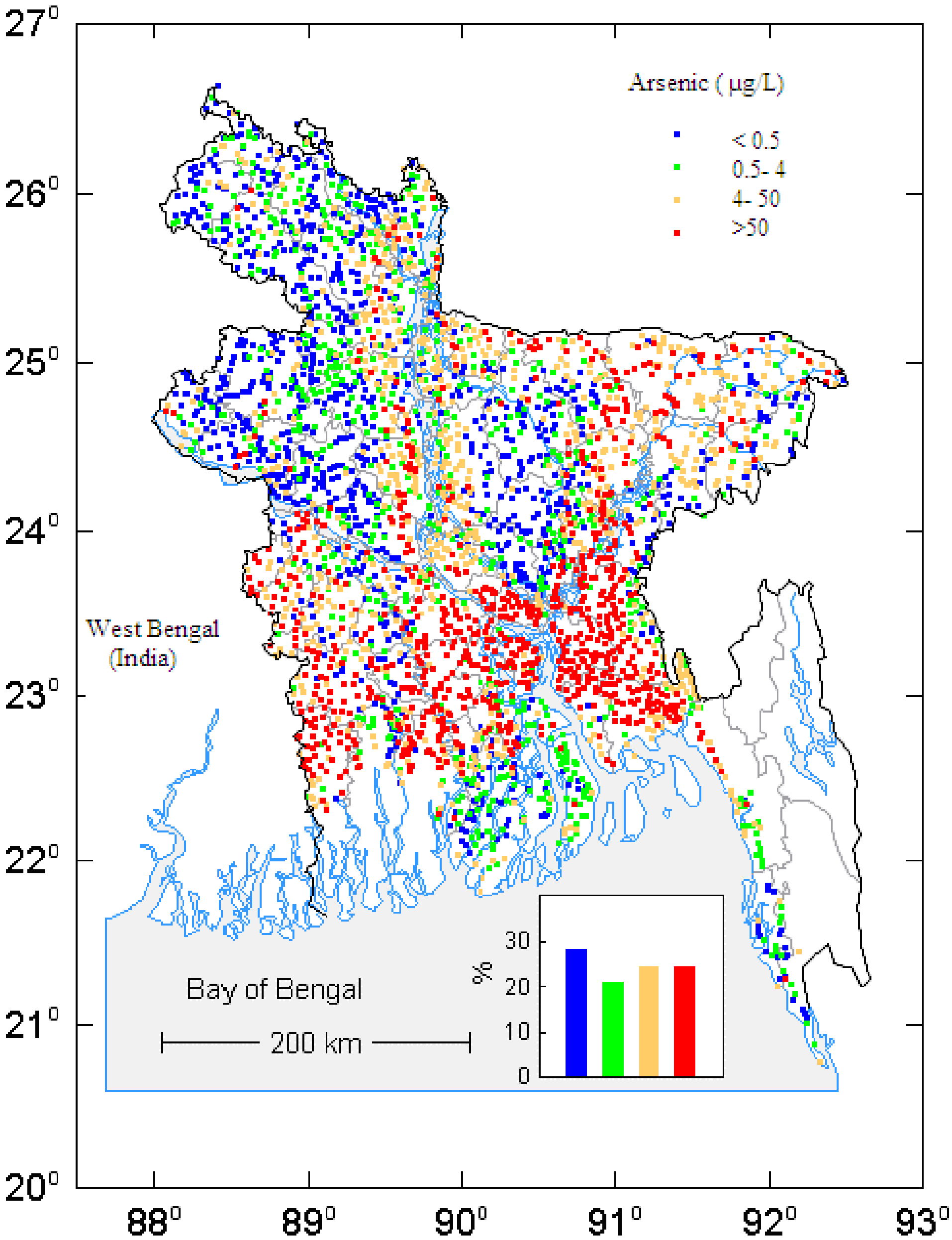


Figure 3: Arsenic concentrations in groundwater in Bangladesh (modification of BGS and DPHE, 2001)

All over the country, about 4 million tube wells (hand pumps) have been sunk into aquifers located at depths ranging from 40 to 300 ft. Of the tube wells so far examined in the 60 districts, 50% contained arsenic at levels above the Bangladesh safe limit (0.05 mgL^{-1}); the highest concentration of arsenic detected in tube well water is 2.97 mgL^{-1} (Ahmad et al., 2001).

On the other hand, shallow hand-dug wells are usually uncontaminated from As though they may be highly contaminated with microbes. Surface water (pond, river, lakes) are also seemed to be completely free from arsenic.

Explanations of As mobilization in ground-water aquifer of Bangladesh

There are several hypotheses to explain the problem of As-enrichment in ground-waters of Bangladesh. At first, use of fertilizers, pesticides, insecticides, waste disposal, As compound treated wooden poles etc. were blamed as the anthropogenic sources of As-enrichment in groundwater (NRECA, 1997). Regional occurrence of As in groundwater of Bangladesh is however not attributable to any anthropogenic activities, and the current status of knowledge indicates predominantly geogenic source and its release in groundwater through natural processes (Bhattacharya et al., 1997; Nickson et al., 1998, 2000). Oxidation of pyrite (FeS2) or arsenopyrite (FeAsS) was postulated as the dominant process for As mobilization due to lowering of water table following excessive pumping of groundwater (Mallik and Rajagopal, 1996) that was widely accepted at the beginning. This hypothesis is also known as pyrite oxidation hypothesis.The basic concept of hypothesis is that the early Pleistocene sediments in the Bengal Basin were exposed and oxidized due to sea level draw down. Sea level rose during the late Pleistocene-early Holocene filling entrenched channels with gravel and sand. Both these sediment packets are generally free of arsenic problem. Arsenic contamination in groundwater in the Bengal Basin is essentially confined to the early-mid Holocene deltaic sediments. Deltaic setting was induced by rapid rise of sea level around 10,000-7500 yr. ago. Now-a- day’s people are using tube well water and deep tube well water for drinking, cooking, irrigation and other purposes. Scientists are thinking that ground water level is going down day –by- day due to pull up excess water. The gaps are now filling with oxygen and this oxygen is mixing with the sediments arsenic. As a result, the inactive arsenic became active and transfer into active form arsenate.

Another theory, known as the Fe oxyhydroxide reduction hypothesis, is now widely accepted as the principal mechanism of As mobilization in the ground waters of the alluvial aquifers of the GBM Delta (Bhattacharya et al., 1997; Nickson et al., 2000; Routh et al., 2000; McArthur et al., 2001; Dowling et al, 2002; Anwar et al., 2003). Arsenic mobilization in groundwater also appears to be triggered by intensive extraction of groundwater for irrigation and application of phosphate fertilizer. On the other hand, Harvey et al. (2002) report that As mobilization is associated with recent inflow of C due to large scale irrigation pumping. Foster et al. (2000) and Breit et al. (2001) report that apart from Fe(III)-oxyhydroxides, other solid phases such as phyllosillicates also play an important role in As cycling and mobilization.

Inorganic arsenic is more mobile than organic arsenic, and thus poses greater problems by leaching into surface waters and groundwater (NRCC , 1978).Metal sulfide and sulfide concentrations, temperature, salinity appear to be significant factors that determine the fate and transport of As (Ning, 2002). Evaporation of surface water may cause the accumulation of arsenic in shallow ground water (Welch and Lico , 1998).

Arsenic in ground-water of other countries

In Muzaffargarh District of south-western Punjab, central Pakistan, the concentrations of As in ground water exceeded WHO provisional guideline value (10 μgL^{-1}) and reached up to 906 μg^{-1} (Nickson et al., 2000).

Berg et al. (2001) found As concentrations up to 305 μgL^{-1} in groundwater in the Red River delta. Little is known about the As concentrations in groundwater from the middle and upper parts of the Mekong Delta (and into adjacent Cambodia and Laos) and other smaller alluvial aquifers in Vietnam (Smedley and Kinniburgh, 2002).

In Southern Australia a large area has been contaminated with As (ranging between 20 and 1000 mg /Kg) due to repeated use of As based pesticides and herbicides (Smith et al., 2006).As levels in groundwater in the North of Perth, Australia, where concentrations of As in peat commonly exceed 100 mg Kg^{-1} and over 1000 mg Kg^{-1} in some localities (Appleyard et al., 2006).

William and Smith (1994) found concentrations up to 72 μgL^{-1}As in acidic waters of a mining area in Zimbabwe. Smedley (1996) reported As concentrations up to 350 μgL^{-1} in stream waters affected by mining pollution in the Obuasi area of southern Ghana. However, no regions in Africa have been identified with high concentrations of As in groundwater, and no health problems related to groundwater As are yet known. Concentrations of As above 50 μgL^{-1} have been identified in groundwater from alluvial sediments in the southern part of the Great Hungarian Plain of Hungary and neighbouring Romania (Smedley and Kinniburgh, 2002).

Arsenic in groundwater is becoming a problem in many Mexican regions, La Comarca Lagunera, San Luis Potosi, Salamanca, Andocutin, Zimapán and others (Parga et al., 2005). Arsenic contamination has been found in well water from several communities ranging from 240 to 1000 μgL^{-1}.

Singh and Mostey (2003) showed in their study that the concentrations of trace metals (As, Cd, Cr, Cu, Hg, Pb, and Zn) in the major drinking water supplies of Viti Levu, Fiji were found to be low and no risk to human health.

Impact of arsenic in Human-being

Arsenic in very dangerous for human- being and causes a special disease called arsenicosis. A good number of studies have been conducted in Bangladesh to find out the effect of As in human-being. In Bangladesh, it is reported that about 200,000 people are suffering from arsenicosis (Figure 4) ranging from melanosis to skin cancer (Das, 2000).

Figure 4: Effect Arsenicosis on human body (after Banglapedia)

In human body ingested arsenic is quickly transported into the liver. Inorganic arsenic is a potent metabolic poison that affects some of the oxidative reactions associated with the breakdown of sugar for energy generation. The degree of methylation of arsenic apparently correlates with the toxicity of arsenic with one methyl group is more toxic than arsenic with three methyl groups. While an arsenic compound is bio-transformed, the relevant biological system, specially the cells involved, is also affected (Tian et al., 2000). Clinical symptoms of arsenicosis are Melanesia (dark patches on the skin), Leukomelanosis (white skin patches) and Keratosis (hardening of skin) Over time, these symptoms can become more pronounced and in some cases, internal organs including the liver, kidneys and lungs can be affected. In the most severe cases, cancer can occur in the skin and internal organs, and limbs can be affected by gangrene (Rahman, 1999; Yu et al., 2003). While evidence links arsenic with cancer, it is difficult to say how much exposure and for what period of time, will result in cancer. The World Health Organization (WHO) estimates that these symptoms can take 5 to 10 years of constant exposure to arsenic to develop.

Besides arsenicosis adverse pregnancy outcomes (e.g. abortion, stillbirth, and preterm birth) are more common among women who are chronically exposed to arsenic through drinking water (Ahmad et al., 2001).

Arsenicosis and social problem

Literacy rate in Bangladesh is 41% and most the village people are illiterate. Most of Arsenicosis patients live in the rural areas of Bangladesh as most of villagers use shallow tube-well water. On the other hand the city duellers are receiving treated water from the urban water authorities and they are capable to pay for that. So, more than 60 million village people are in danger for the arsenic contamination in Bangladesh and most of them are poor. More over the poor nutritional status may increase an individual's susceptibility to chronic arsenic toxicity (Milton el at., 2004). In Bangladesh arsenicosis causes 9,136 deaths and 174,174 disability-adjusted lives in every year (Lokuge et al., 2004). Study of McDonald et al. (2006) identified cancer and skin lesion to the people of Bangladesh who live in the area with average drinking water As concentrations level more than 50 μgL^{-1} . The patients with several arsenic diseases are facing tremendous social problems. Unfortunately there is an inadequate study on this aspect. Village people think that arsenicosis is a course rather that treat it as a disease. The young girls affected with Arsenicosis facing problem to get married and the other family members think that they are the burden for the whole family. Arsenicosis affected male also face problem to get married and also to get work. Most the Arsenicosis patients deliberately try to hide their problems and reluctant to go for medication due to the fear that other people may know their problems. Lokuge et al. (2004) reported that the children with Arsenicosis are not sending to school due to intolerable environment. Other students do not want to play with them and also not interested to make friendship. Arsenicosis patents need improve diet and long time medication to get recovery from the disease but most the village people are poor and they have no capacity to manage improve food and money for the medication.

It may take long time (10-15 years) to expose arsenicosis in infected people. So, the people who are taking As rich water and food do not know what is going in future. Though it is estimated that the about 174,174 people are suffering from arsenicosis every year but the number will be definitely significantly increased in future.

Other trace metals in ground-water and soil of Bangladesh

Some studies has been conducted to find out the concentration other heavy metals in ground water of Bangladesh (Table 5) but no study has been conducted to find out the presence and effect of other metals in ecosystem in Bangladesh . Frisbie et al. (2002) reported that the concentrations of As, manganese (Mn), lead (Pb), nickel (Ni), and chromium (Cr) exceeded WHO or U.S. Environmental Protection Agency (U.S. EPA) health-based drinking water criteria in Bangladesh. Approximately 50% of Bangladesh's area may contain groundwater with Mn concentrations greater than the WHO health-based drinking water guideline (Frisbie et al., 2002). Pb (3% of Bangladesh's area), Ni (< 1% of Bangladesh's area), and Cr (< 1% of Bangladesh's area) concentrations also exceed WHO health-based guidelines (Frisbie et al., 2002) (Table,13).In addition, the BGS/DPHE (2001) study suggested that 5.3%, 0.3%, and an unspecified percentage of Bangladesh's tube-wells exceed the WHO health-based drinking water guidelines for boron, barium, and molybdenum, respectively. Moreover, the BGS/DPHE study suggests that 12–50% of Bangladesh's tube-wells exceed the WHO health-based drinking water guideline for uranium.

Chromium is found in the soil as chromite ($FeOCr_2O_3$) (Daugherty, 1992). The predominant occurrence of chromium in water, soil and rocks is the trivalent state, which is non-toxic and an essential dietary nutrient (Morrison, 2003). However, chromium is very carcinogenic to human depending on the valence state. Copper is found in the soil and used in many manufacturing processes and is toxic to the human body in large doses (Faust, 1992; Roth, 2003). Copper is necessary and essential to support many actions within the body. Copper is used in cytochrome oxidase (energy metabolism), superoxide dismutase (antioxidant), histaminase (allergies), lysil oxidise (collagen and elastin), tyrosinase (pigmentation), and dopamine-beta-hydroxylase (cofactor for norepinephrine) (Roth, 2003). However access doses of Cu is harmful for human and may cause mental problems, schizophrenia, and learning disabilities (Roth, 2003).

Manganese is a very common trace metal of soil. It may be found in valance states from (III) to (VII), with (IV) being more common for manganese dioxide (Barceloux, 1999). Manganese is essential in protein and carbohydrate metabolism, bone formations and cholesterol (Roth, 2003).Nevertheless high level of Mn can cause central nervous system and respiratory tract disorder (Levy and Nassetta, 2003).Selenium was originally studied for its toxicity in livestock and poultry (Tuormaa, 1995). Recently selenium has been shown to mitigate the affects of arsenic poisoning in China (Wang et al., 2001). The dietary mechanism for incorporation of selenium into the body is through ingestion of plant and animal products that are grown in soils which contain selenium (Tapiero et al., 2003).

A very few studies has been conducted to determine the soil trace metals in Bangladesh. The average soil content ($\mu g g^{-1}$) for selinium (Se) , copper (Cu), chromium (Cr), cadmium (Cd) and manganese (Mn) is Se (< 0.05), Cu (75.1), Cr (61.0),Cd (5.04) and Mn (467.5) (Spallholz et al.,2008). On the other hand , the study of Ahsan et al. (2008) shows that the concnetration of soil Cr (~ 75 mg kg^{-1}) and Co (~ 16.41 mg kg^{-1}) has exceeded the world average level. However some studies showed that Bangladesh soil and water are very deficit with Se (Ahsan et al.,2008; Oldfield, 2002; Frisbie et al.,2002).

Table 5: Risk-based drinking water criteria and the percentage of area exceeding these criteria (Frisbie et al., 2002)

	Risk-based drinking water criteria (mg/L)		Percentage of Bangladesh's area exceeding criteria	
Element	WHO	US EPA	WHO	US EPA
As	0.010	0.010	49	49
Ba	0.700	2.000	0	0
Cd	0.003	0.005	0	0
Cr	0.050	0.100	< 1	0
Cu	2.000	1.300	0	0
F	1.500	4.000	0	0
Mn	0.500	None	50	NA
Mo	0.070	None	0	NA
Ni	0.020	0.100	< 1	< 1
Pb	0.010	0.015	3	2
Sb	0.005	0.006	0	0
Se	0.010	0.050	0	0
TI	None	0.002	NA	0

NGO and pollution control in Bangladesh

Non Governmental Organization popularly known as NGO is a very widely known terminology all over the world especially for the developing world. It is very difficult to define NGO but in broadest sense NGOs mean non governmental, non profitable organizations which main vision is to serve the poor and disadvanced group of the society. They are involved with micro-credit, environment, family planning, education, heath and sanitation, human right and many other sectors of the society. NGOs serve their philanthropic purpose typically by collecting funds from the public or from donors (Barr et. al., 2005).

Reason behind the emergence of environmental NGOs in Bangladesh

Bangladesh has one of the largest and most sophisticated NGO sectors in the developing world. Over 90% of villages in the country had at least one NGO in 2000 (Fruttero & Gauri, 2005) and foreign assistance to the country channelled through NGOs has been above 10% since 1993 (Ahmad, 2002). NGOs are playing active role in every sector like education, health care, family planning, women empowerment and human right, environment and others.

Bangladesh is facing trouble in good governance like many other developing countries. The country is also over loaded with huge population. The literacy rate is very low. So here the main vision of the governmental is to provide food and shelter of huge population. Government put more emphasis on industrializations and urbanization. More over there are severe lacking of transparency and accountability in government. So the government is not very much committed to protect wetland and ecosystem though there several environmental legislations are available in the country. So the wetlands of Bangladesh are squeezing day by day due to population pressure, industrialization and urbanization. More over wetlands protection and ecosystem conservation regulations are not properly implementing because the polluters and encroachers are very powerful and most of them are businessmen, member of parliaments or their relatives and the relative of law enforcing officials. Some of the governmental officials are dishonest. There are some honest officers in law enforcement agents but they cannot do anything due to fear of bad posting to remote area, loss of the promotion even due to fear to loss the job.

Officially Department of the Environment (DoE, the sister organization of the Ministry of Environmental and Forest) is the agent to enforce the environmental laws. Unfortunately this is the weakest department of the government. Even the Ministry of Environment and Forest itself is very weak. DoE is severely lacking of manpower. They have few officials only in six divisional headquarters. They have very few inspectors who based on divisional headquarters. It is very difficult to monitor the situation all over the country. More over it has been mentioned that most of the officials are dishonest.

To overcome the situation in 1980's several environment NGOs, civic society and research organization emerged to work in environmental sectors. BAPA, BCAS, NACOM, CNRS, BELA, Ongikar Bangladesh Foundation, CARDMA, FEJB etc are the prominent environmental NGOs of Bangladesh. Both the NGOs and the donor agencies are creating pressure to government to take necessary initiative to protect the environment and ecosystem. However the attempt which has been taken by the government is not satisfactory and inadequate. On the other hand there are some allegations against NGOs also. As Bangladeshi NGOs including the environmental ones are heavily dependent on foreign resources, the flow of money from the outside, in the absence of accountability, can make the NGOs corrupt, controversial and autocratic (Zarren, 1996). Despite the negative effects in most cases, NGOs are accountable to the donor countries rather than the state of Bangladesh. There have been a large number of case studies and assessments of NGOs in Bangladesh**.** But the role of environmental NGOs on pollution control, wetland management and their relationships to government and to donors and international NGOs have not been addressed.

Rice is the sample food of the Bangladeshi people and also the major agricultural products. Arsenic contaminated shallow tube-wells water is also using for irrigation to cultivate food grains and vegetables all over the country. So, the top soil of Bangladesh is also at high risk to contaminate with arsenic. From soil arsenic, can inter into the total food chain and infect human as well. It has been found that a large amount of the arsenic in marine organisms is in organic forms such as arsenosugars in algae, and arsenobetaine and arsenocholine in fish, mollusks, and crustaceans (Francesconi et al., 1994). However, terrestrial plants do not have arsenic detoxification system of algae by methylation of arsenic, and this is perhaps the reason why inorganic arsenics species are predominant in terrestrial plants (Mattusch et al., 2000). Unfortunately inorganic As is very dangerous to human-being. However, limited studies (Meharg et al., 2003; Duxbury et al., 2002; Abedin et al., 2002; Das et al., 2003 and Alam and Rahman, 2003) have been conducted to assess the presence of arsenic in soil, rice and several vegetables of Bangladesh. Those studies show that As can accumulate in soil and from soil to vegetables and rice. Again, most of the previous studies were only based on As rather than to estimates the status of all trace metals in soil and food materials.

It is very important to know the status and mobility pattern of arsenic and other trace metals. However, no studies have been deigned to understand the mobility patterns of As and others trace metals in agricultural soil of Bangladesh. Although the total concentration of trace elements in soil gives some indication of the level of contamination, it provides no insight into the bioavailability or mobility of the elements. Trace metals in soil are associated with a number of physicochemical forms that in turn influence the availability. So, a comprehensive knowledge of the interactions between the trace elements and the soil matrix are required to judge their environmental impact. Chemical speciation is the most common technique to understand the behavior of metals in natural system.

As mentioned earlier, there have been a large number of case studies and assessments of NGOs in Bangladesh (Fruttero and Gauri, 2005) but the role of ENGOs on wetland management, environmental pollution control and their relationships to the government and to donors have not been addressed.

1.2 Location of the study area

The surface soils samples were collected from floodplain agricultural fields of Faridpur (l23^{0}10$^/$ to 23^{0}40$^/$ N and 89^{0}35$^/$ to 90^{0}10$^/$ E) and Dhamrai (23^{0}50$^/$ to 24^{0}05$^/$ N and 90^{0}00$^/$ to 90^{0}20$^/$ E) of Bangladesh during dry season (15th to 29th December, 2006) (Figure 5). The ground-water of Fardipur is heavily contaminated with As and other tarce metals . However the ground-water of Dhamrai is not contaminated with As and other trace metals . In both the reiongs, ground water has been using for irrigation of paddy field for long time (Figure 6 and 7).

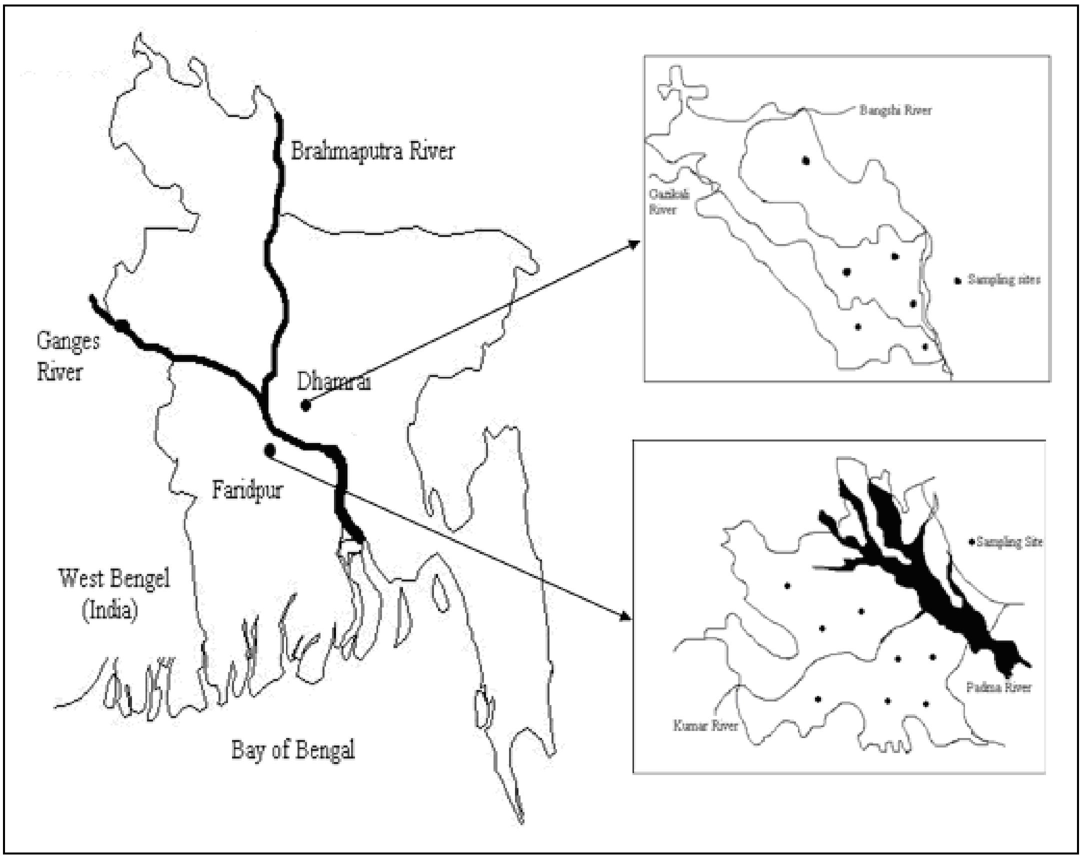


Figure 5: Map of Dhamrai and Faridpur of Bangladesh (with location of sampling sites)

Figure 6: Paddy field in Dhamrai region

Figure 7: Paddy field (irrigated with ground water) in Faridpur region

1.3 Hypothesis

The present study has been based on following hypothesis:

Ground water is the major source of water for irrigation in Bangladesh. Arsenic and trace metal contaminated ground water has been using for irrigation of paddy fields for a long time. It is predicted that arsenic and trace metals rich irrigated water can increase As and trace metals level of the agricultural top soil. The flood plain agricultural soil of faridpur may contain significant amount of trace metals specially As than the soil of Dhamrai as the ground water of Faridpur region is heavily contaminated with As. Moreover, the agricultural soil of both the study areas may be contaminated with other trace metals like Ni, Mn, Cu, Se, Zn, Fe, Pb, Cd, Cu and Cr as much of Bangladesh ground water is also enriched with those metals.

Soil arsenic and trace metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Fe, Hg and Zn) of study area are mobile and ready avaible for rice plants, wheat plants, vegetables and other crops. It is also hypotheised that due to mobility of trace metal, agricultural soil of the study area is polluted with the trace metals and ecotoxicological risk is high in the study area.

Bangladeshi ENGOs have strong relationship with government organizations, international ENGOs and donor agencies and their role is praiseworthy. The present study assumes that all the environmental NGOs are receiving money from the international donors and ENGOs are very concern about their accountability. This study also assumes that ENGOs of Bangladesh are also acting as a pressure group to control the environmental pollution.

Hipótesis planteadas

El estudio plantea las siguientes hipótesis:

i) Los suelos agrícolas de Bangladesh están enriquecidos con As y metales trazas, con especial incidencia los lugares que han sido contaminados con aguas subterráneas

ii) Las aguas de riego con alto contenido en As, son el origen principal del As presente en el suelo.

iii) La presencia de Se en los suelos y en las aguas subterráneas es insuficiente para actuar como mecanismo de protección frente a los efectos carcinogénicos.

iv) Los metales presentes en los sedimentos se encuentran significativamente correlacionados con los niveles de otros metales.

v) Las organizaciones no gubernamentales (ONGs) de Bangladesh mantienen estrechos contactos con otras ONGs internacionales y deben ejercer un papel activo ante los centros de investigación a fin de proteger el medio ambiente (llanuras aluviales y humedales) de los problemas de la contaminación.

Objectives of the study

The aims of the present study are;

i) Understand the impact of irrgiation with As and other trace metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Fe, Hg and Zn) rich ground-water on flood plain agricultural soil of Bangladesh

ii) Understand the mobility patters of As and other metals in floodplain agricutiral soils

iii) Assess the enviornmnetal risk of As and other trace metals in Bangladesh

iv) Explore the role of environmental NGOs to protect the wetlands and to control the environtmeal pollution in Bangladesh and their relation with governmental agencies, donor agencies and international ENGOs

In addressing the above mentioned aims the present study intends to achieve the following objectives;

i) to determine the distribution of As, Cu, Pb, Mn, Fe, Zn, Co, Se, Hg, Cd, Cr and Ni in floodplain agricultural soil of Bangladesh

ii) to conduct the BCR sequential extraction procedure for the determination of arsenic and other eleven trace metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Fe, Hg and Zn) in soils of Bangladesh to evaluate the mobility and the risk assessment for arsenic and other trace metals

iii) to find out the role of ENGOs to prevent environmental pollution and to protect and manage wetlands in Bangladesh

Objetivos del estudio

La elevada presencia de arsénico en las aguas subterráneas de Bangladesh, y el uso de éstas para riego ha generado un problema de salud pública. En consecuencia en esta Tesis se plantean los siguientes objetivos:

i) Estudiar la distribución del metaloide As y otros metales trazas (Cu, Ni, Fe, Zn, Cr,Cd, Pb, Se, Co, Hg and Mn) en suelos agrícolas y llanuras aluviales.
ii) Analizar la biodisponibilidad de As y metales trazas (Cu, Ni, Fe, Zn, Cr, Cd, Pb, Se, Co, Hg and Mn) en suelos de Bangladesh
iii) Evaluar el posible impacto de las concentraciones de As y los metales trazas (Cu, Ni, Fe, Zn, Cr, Cd, Pb, Se, Co, Hg and Mn)
iv) Examinar la implicación de las ONGs a nivel nacional e internacional en el control de la contaminación y la protección de los humedales.

1.4 Estructura de la tesis

En lo que respecta a la organización de esta Memoria, se ha estructurado de una forma distinta a la manera clásica y se ha optado por separar la misma en varios Capítulos en los que se incluyen trabajos de investigación escritos en el idioma Inglés y que han sido, bien publicados, bien aceptados o están bajo recensión en revistas internacionales. Además, y debido a las características del programa de Doctorado con mención de calidad 'Gestión de Agua y Costas' asociado al master de calidad de la unión Europea 'Master Erasmus Mundus in water and Coastal management' el idioma inglés ha prevalecido durante la realización de esta tesis aunque se han incluido en Español los siguientes apartados para facilitar su lectura y análisis en nuestro país: Objetivos, hipótesis, estructura de la tesis y conclusiones. De esta forma, se confiere una entidad de Tesis Doctoral a este compendio de trabajos de investigación que siguen, por otra parte, *un objetivo general común. Además, se ha mantenido un capítulo de organización clásica, como es el inicial de Introducción y Objetivos y se ha optado por reflejar las conclusiones de cada capítulo en un apartado final para cada uno de los capítulos, que forman la tesis lo que recalca el carácter de trabajo conjunto e integrado de la presente Memoria.*

Así, en el Capítulo 2, se incluye el trabajo relativo a la revisión del estado de riesgo en el que se encuentran los ecosistemas y la salud humana de Bangladesh por contaminación por metales y especialmente por el metaloida As. En el mismo se identifican las principales vías de exposición y actividades que estan asociados con el aumento del riesgo de efectos asociados con este tipo de contaminación. En el capítulo 3 se presentan los resultados de la distribución del arsénico y de los metales traza en suelos de llanuras aluviales en diferentes áreas localizadas en Bangladesh. Los resultados muestran el elevado riesgo que existe en las zonas estudiadas asociado con las concentraciones excesivas de arsénico que en algunos lugares supera más de 5 veces la permitida por diferentes organismo internacionales, tanto en suelos como en aguas subterráneas y acuíferos. En el capítulo 4 se lleva a cabo un estudio de las diferentes asociaciones de los metales y el arsénico en las fracciones geoquímicas de los suelos estudiados con el objetivo de estudiar mas en detalle las posibles implicaciones de la movilidad de estos contaminantes en la evaluación de riesgo en las zonas de suelos de llanuras aluviales de Bangladesh. Los resultados muestran como ciertos metales como el Cd se muestran asociados con las fracciones mas móviles de los suelos y por tanto asociados con un mayor riesgo, tanto para el ecosistema como para la salud humana por consumo de aguas y otras matrices ambientales contaminadas. Sin embargo, el estudio concluye que ciertas zonas estudiadas aunque con concentraciones elevadas de As no presentarían un elevado riesgo ya que éste metaloide estaría asociado a las fracciones menos móviles del suelo.

En el capítulo 5 de esta memoria de tesis se muestran las características de actuaciones de diferentes ONGs relacionadas con el control de la contaminación de las zonas de llanuras aluviales de tanta productividad agrícola en Bangladesh y su relación con la economía y la salud de la población de las mismas. Los resultados muestran que una estrecha colaboración entre las ONGs nacionales y el gobierno del país pueden disminuir significativamente el riesgo en la zona. La colaboración con ONGs *internacionales con objetivos similares mejoraría significativamente los resultados obtenidos en el control de la contaminación de la zona y sus efectos sobre el ecosistema y especialmente sobre la población que habita las áreas estudiadas.*

Finalmente, en el último capítulo se incluyen las conclusiones obtenidas durante la discusión y análisis de los diferentes estudios tomados como un único trabajo de investigación reflejado en esta memoria de tesis doctoral.

1.5 Bibliografía

Abedin M J, Malcolm S, Andy A, Cotter-Howells J (2002). Arsenic accumulation and metabolism in rice (*Oryza sativa*). Environ. Sci. Technol. 36: 962 -968

Ahmad M (2002). An introduction to the non-profit sector in Bangladesh. Allavida, London

Ahmad S A , Salim M H, Sayed U, Barua S, Khan M H, Faruquee M H, Jalil A, Hadi S A, and Talukder H K (2001). Arsenic in Drinking Water and Pregnancy Outcomes . Environmental Health Perspectives, 109 :629-631

Ahmed M F (2003). Arsenic contamination of groundwater in Bangladesh, In: Ahmed, M.F. (Ed.) Arsenic contamination: Bangladesh Perspective. ITN-Bangladesh, Dhaka, pp 42-62

Ahsan D A, DelValls T A , Blasco J (2008). Distribution of arsenic and trace metals in the floodplain agricultural soil of Bangladesh. Bull. Environmental Contam. Toxicol. (published online)

Alam A, Rahman A (2003). Accumulation of arsenic in rice plant from arsenic contaminated irrigation water and effect on nutrient content. In: Ahmed M F, Ali M A and Adeel Z (Eds) Fate of arsenic in the environment. Proceedings of the International Symposium on Fate of Arsenic in the Environment, ITN Centre, BUET, Dhaka

Ali M (2003). Review of drilling and tubewell technology for groundwater irrigation. In: Groundwater resources and development in Bangladesh. The University Press Limited, Dhaka, Bangladesh

Anawar H M, Akai J, Komaki K, Terao H, Yoshioka T, Ishizuka T, Safiullah S, Kato K (2003). Geochemical occurrence of arsenic in groundwater of Bangladesh: sources and mobilization processes. J. Geochem. Explor. 77:109– 131

Anawara H M, Akaib J, Mostofac K M G , Safiullahd S, Tareqd S M (2002) . Arsenic poisoning in groundwater - health risk and geochemical sources in Bangladesh. Environment International, 27:597-604

Appleyard S J, Angeloni J, Watkins R (2006). Arsenic-rich groundwater in an urban area experiencing drought and increasing population density, Perth, Australia. Applied Geochemistry, 21: 83-97

Banglaperdia, 1999. Bengal Academy, Dhaka, Bangladesh

Barr A, Fafchamps M, Owens T (2005). The governance of non-governmental organizations in Uganda. World Development , 33: 657-679

Berg M, Tran H C, Nguyen T C, Pham H V, Schertenleib R, Giger W (2001). Arsenic contamination of groundwater and drinking water in Vietnam: a human health treat. Environmental Sci. Technol. 35: 2621-2626

BGS and DPHE (2001) Arsenic contamination of groundwater in Bangladesh. In: Kinniburgh, D.G. and Smedley, P.L. (Eds.) BGS Technical Report WC/00/19, volume 1: Summary. British Geological Survey, Keyworth

Bhattacharya P, Chatterjee D, Jacks G (1997). Occurrence of arsenic contaminated groundwater in alluvial aquifers from Delta Plains, Eastern India: Options for safe drinking water supply. Int. Jour Water Res. Management, 13:79-92

Breit G N, Foster A L, Sanzalone R F, Yount J C, Whitney J W, Welch A H, Islam M K, Islam M N (2001). Arsenic cycling in eastern Bangladesh: the role of phyllosilicates.Geol. Soc. Am., Abstracts with Programs 32 (7), A192

Cai Y, Cabrera J C, Georgiadis M, Jayachandran K (2002). Assessment of arsenic mobility in the soils of some golf courses in South Florida. Sci. Total Environm. 291:123-134

Chakroborti D, Rahman M M, Paul K (2001). Groundwater arsenic contamination in South East Asia with special reference to Bangladesh and West Bengal-India, Arsenic in the Asia Pacific Region Workshop, Adelaide, Managing Arsenic for the Future: 1-4

Chowdhury UK, Biswas B K, Chowdhury T R, Samanta G, Mandal B. K, Basu G C, Chanda C R, Lodh D, Saha K C, Mukherjee S K, Roy S, Kabir S, Quarmruzzaman Q, Chakraborti D (2000). Groundwater arsenic contamination in Bangladesh and West Bengal, India. Environ Health Persperct. 108(5): 393-397

Das H K (2000). Bangladeshe Arsenic: Bhayabahata O Sambhabbya Protikar. Bangla Academy, Dhaka, pp. 1-278

Das H K, Chowdhury D A, Rahman S, Obaydullah M, Sengupta P , Islam F (2003). Arsenic contamination of soil and waterand related bio-hazards in Bangladesh. In: Ahmed M F, Ali M A and Adeel Z (Eds) Fate of Arsenic in the environment. Proceedings of the International Symposium on Fate of Arsenic in the Environment, ITN Centre, BUET, Dhaka

Dowling C B, Poreda R J, Basu A R, Peters S L (2002). Geochemical study of arsenic release mechanisms in the Bengal Basin groundwater. Water Resour. Res. 38: 1173– 1190

Duxbury J M, Mayer A B, Lauren J G, Hassan N (2002). Arsenic Content of Rice in Bangladesh and impacts on Rice Productivity, 4th Annual Conference on Arsenic Contamination in Groundwater in Bangladesh: Cause, Effect and Remedy, Dhaka

EPA (1980). Ambient water quality criteria for arsenic. U.S. Environ. Protection Agency Rep. 440/5-80-021, pp 205

EEA (European Environment Agency) (1999). Groundwater quality and quantity in Europe. Environmental assessment report no 3

Francesconi K A, Edmonds J S, Morita M (1994). Determination of arsenic and arsenic species in marine environmental samples. In: Nriagu J O (Ed) Arsenic in the Environment Part I: Cycling and characterization. John Wiley and Sons, Canada, pp 189 –219

Frisbie S H,Ortega R, Maynard D M, Sarkar B (2002). The Concentrations of Arsenic and Other Toxic Elements in Bangladesh's Drinking Water. Environ. Health Pers. 110: 1147-1152

Fruttero A, Gauri V (2005) . The strategic choices of NGOs: Location decisions in rural Bangladesh. J. Develop. Studies, 41: 759–787

Foster A L, Breit G N, Welch A H, Whitney J W, Yount J C, Islam M S, Alam M M, Islam M K, Islam M N (2000). In-situ identification of arsenic species in soil and aquifer sediments from Ramrail, Brahmnabaria, Bangladesh. Eos Trans Am. Geophys. Union 81 (48), F523

Goessler W , Kuehnelt D (2002) . Analytical methods for the determination of arsenic and arsenic compunds in the environment. In: frankeberge WT (Ed). Environmental chemistry of arsenic. Marcel Dekker. New york, USA, pp 27-50

Goh K H , Lim T T (2005). Arsenic fractionation in a fine soil fraction and influence of various anions on its mobility in the subsurface environment. Applied Geochemistry, 20: 229-239

Harvey C F, Swartz C H, Badruzzaman A B M, Keon- Blute N, Yu W, Ali M A, Jay J, Beckie R, Nieden V, Brabander D, Oates P M, Ashfaque K N, Islam S, Hemond H F, Ahmed M F (2002). Arsenic mobility and groundwater extraction in Bangladesh. Science 298: 1602– 1606

Levy B S, Nassetta W J (2003). Neurological effects of manganese in humans: a review. Int. Journal Occii. Environ. Health. 9: 153-63

Lokuge K M, Smith W, Caldwell B, Dear K, Milton A (2004). The effect of arsenic mitigation interventions on disease burden in Bangladesh. Environmental Health Pers. 112 : 1172-1177

Lombi E, Sletten R S, Wenzel W W (2000). Sequentially extracted arsenic from different size fractions of contaminated soils. Water Air Soil Pollut. 124: 319-332

Mallik S, Rajagopal N (1996). Groundwater development in the arsenic-affected alluvial belt of West Bengal— Some questions. Curr. Sci. 70: 956–958

Mandal B K , Suzuki K T (2002) . Arsenic round the world: a review. Talanta, 58: 201-235

Matschullat J (2000). Arsenic in the geosphere – a review. Sci. Total Environ. 249 : 297-312

Mattusch J, Wennrich R, Schmidt A C (2000). Determination of arsenic species in water, soils and plants .Fr. Esenius. J. Anal. Chemistry, 366:200 –203

McArthur J M, Ravencroft P, Safiullah S, Thirlwall M F (2001). Arsenic in groundwater: testing pollution mechanism for sedimentary aquifers in Bangladesh. Water Resour. Res. 37: 109–117

Meharg A A, Rahman M (2003). Arsenic contamination of Bangladesh paddy field soils: implications for rice contribution to arsenic consumption. Environ. Sci. Technol. 37: 229–234

Milton A H, Hasan Z, Shahidullah S M, Sharmin S, Jakariya M D, Rahman M, Dear K , Smith W (2004). Association between nutritional status and arsenicosis due to chronic arsenic exposure in Bangladesh. International J. Env. Health Res.14 : 99 -108

Monan J (1995). Bangladesh: The Strength to Succeed. Oxfam, UK

Narcise CIS, Coo L, del Mundo FR (2005). On-line preconcentration and speciation of arsenic by flow injection hydride generation atomic absorption spectrophotometry. Talanta, 68 : 298-304

NAS (1977). Arsenic. Natl. Acad. Sci., Washington, D.C. pp 332

NRECA (1997). Report of study of the impact of the Bangladesh rural elctrification program on groundwater quality. Prepared for Bangladesh Rural Electrification Board by NRECA International with personnel provided by The Johnson Company Inc. (USA) and ICDDR, B (Dhaka) for USAID

Nickson R, McArthur J, Burgess W, Ahmed M, Ravenscroft P, Rahman M (1998). Arsenic poisoning of groundwater in Bangladesh. Nature, 395: 338

Nickson R T, McArthur J M, Ravenscroft P, Burgess K M, Ahmed K M (2000). Mechanism of arsenic release to groundwater, Bangladesh and West Bengal. Appl. Geochem. 15: 403–413

Ning R Y (2002). Asenic removal by reverse osmosis. Desalinisation, 143: 237-241

NRCC (1978). Effects of arsenic in the Canadian environment. Natl. Res. Coun. Canada Publ. No. NRCC 15391, pp 349

Oldfield J E (2002). Selenium world atlas: updated edition. Selenium-Tellurium Development Assn. Grimbergen, Belgium, pp59

Parga J R, Cocke D L, Valenzuela J L, Gomes J A, Kesmez M, Irwin G, Moreno H, Weir M (2005). Arsenic removal via electrocoagulation from heavy metal contaminated groundwater in La Comarca Lagunera Mexico. J. Hazardous Materi. 124: 247-254

Pongratz R (1998). Arsenic speciation in environmental samples of contaminated soil. Sci. Total Environ. 224: 133-140

Rahman M (1999). Nonmalignant health effects of arsenic exposure. Medical Dissertation, Linkoping Univ., Sweden, 59

Ravenscroft P, McArthur J M, Hoque BA (2001) Geochemical and palaeohydrological controls on pollution of groundwater by arsenic. In: Chappell, W.R., Abernathy, C.O., Calderon, R.L. (Eds.), Arsenic Exposure and Health Effects IV. Elsevier Science Ltd., Oxford, pp 53–77

Rosenboom J W, Ahmed K M, Pfaff A, Madajewicz M (2004). Arsenic in 15 Upazilas of Bangladesh: Water supplies, health and behaviour Report prepared for APSU, Unicef and DPHE, Dhaka, Bangladesh

Roychowdhury T, Uchino T, Tokunaga H, Ando M (2002). Survey of arsenic in food composites from arsenicaffected area of West Bengal, India. Food Chem. Toxicol. 40: 1611–1621

Tapiero H, Townsend D M, Tew K D (2003). The anfioxidant role of selenium and seleno-compounds. Biomed. Pharmacother. 57: 134-44

Tuormaa T E (1995). The role of chromium, selenium, and copper in human and animal metabolism. J. Orthomolecular Med. 10:149-164

Sadiq M (1997). Arsenic chemistry in soils: an overview of thermodynamic predictions and field observations. Water Air Soil Pollut. 93: 117-136

Sanders J G (1980). Arsenic cycling in marine systems. Mar. Environ. Res. 3:257-266

Singh S, Mosley L M (2003). Trace metal levels in drinking water on Viti Levu, Fiji Islands. Sci. Pac. J. Nat. Sci. 21: 31-34

Smedley P L (1996). Arsenic in rural groundwater in Ghana. J. African Earth Sci. 22: 549-470

Smedley P L (2003). Arsenic in groundwater – South and East Asia. In: Welch, A.H., Stollenwerck, K.G. (Eds.), Arsenic in Groundwater – Geochemistry and Occurrence, Dordrecht, pp179–210

Smedley PL , Kinniburgh DG (2002). A review of the source, behaviour and distribution of arsenic in natural waters. Applied geochemistry, 17: 517-568

Smith E, Naidu R, Alston A M (1998). Arsenic in the soil environment: a review. Advances in agronomy, 64: 149-195

Smith E, Smith J, Naidu R (2006). Distribution and nature of arsenic along former railway corridors of South Australia. Sci. Total Environment, 363: 175-182

Spallholz J E, Boylan L M, Rahman M M , Katz D (2008). Selenium and arsenic content of agricultural soils from Bangladesh and Nepal. Toxicol. Environmental Chem. 90:203-210

Thornton I (1980). Heavy metal status in soils and standards. In: Reclamation of Contaminated Land, U.K. Pub. by Soc. Chem. Ind., pp: C5/1-12

Tian Y G, Jing F L, Kui W (2000). Arsenite, arsenate and vanadate affect human erythrocyte membrane. Journal Inorg. Biochem. 79:195-203

United Nations Environment Program (UNEP) (1999). Global Environment Outlook. Earthscan, UK

UN/ECE (1999). Inventory of transboundary ground waters. UN/ECE Task Force on Monitoring and Assessment. Guidelines on monitoring of transboundary ground waters. Supporting Technical Documents, Volume 1

Welsch A H, Lico M S (1998). Factors controlling As and U in shallow ground water, southern Carson Desert, Nevada. Applied Geochemistry, 13: 521-539

WHO (1993). Guidelines for Drinking-Water Quality, Vol 1: Recommendations, 2nd ed. Geneva:World Health Organization, pp 39–57, 174

William M W, Smith B (1994). Empirical and modeled hydrochemistry of acid mine drainage, Iron, Duke mine, Mazowe, Zimbabwe. British Geological Survey Tecnhical Report WC/94/78/R. p 24

Woolson E A (Ed.) (1975) . Arsenical pesticides. Am. Chem. Soc. Symp. Ser. 7, pp 176

Yu W H, Harvey C M, Harvey C F (2003). Arsenic in groundwater in Bangladesh: a geostatistical and epidemiological framework for evaluating health effects and potential remedies. Water Resour. Res. 39: 1146

Zarren F (1996). The legal status of NGOs in Bangladesh: a critical assessment. Social Science Review (Bangladesh), 32: 67-90

Internet Reference

Hook J B S (2004).Selenium and arsenic concentration in Bangladeshi soils. MSc thesis, TexasTechUniversity.*http://66.102.1.104/scholar?hl=en&lr=&q=cache:nrzHIC6Pek8J:et*

d.lib.ttu.edu/theses/available/etd07012008312950195304442/unrestricted/31295019530442.pdf+Bangladesh+soil+trace+metals (27/10/08)

Reliefweb: *http://www.reliefweb.int/mapc/asi_sth/reg/reg_bgd.htm ,(10-10-2008)*

Roth R (2003). Copper-Chromium. Acu-Cell Nutrifion. *www.acu-cell.com. (27/10/08)*

CHAPTER 2

(CAPÍTULO 2)

Impact of arsenic contaminated irrigation water in food chain: an overview from Bangladesh

(Paper in under review in the Journal of Ecotoxicology)

Impact of arsenic contaminated irrigation water in food chain: an overview from Bangladesh

D.A. Ahsan · T. A. DelValls · J . Blasco

Authors affiliations:

D.A.Ahsan (✉) · T. A. DelValls

UNESCO/UNITWIN/WiCop. Department of Physical-Chemistry. Faculty of Marine and Environmental Sciences. University of Cadiz, Campus Rio San Pedro, 11510 Porto Real, Cadiz, Spain

e-mail: daahsan@yahoo.com

J. Blasco
Department of Ecology and Coastal Management. Institute of Marine Science of Andalusia (CSIC), Campus Rio San Pedro, 11510 Porto Real, Cadiz, Spain

Abstract Arsenic in ground water is a very serious environmental hazard of Bangladesh and West Bengal of India. The presence of high level of Arsenic (<50 µg/L) in groundwater of Bangladesh has been detected in 1980's. According to World Health Organization (WHO), the permissible limit of arsenic in drinking water is 10 µg/L. 80% of groundwater of the country has been contaminated with arsenic. Nearly 80 million Bangladeshi are now at risk from arsenic related several diseases including cancer. It has been assumed that arsenic is only present in ground water of Bangladesh but some recent studies showed that meantime arsenic had contaminated the agricultural soil as well. A high level of arsenic is also reported food grains and vegetables. The vision of this review is to give an overview of the latest findings of arsenic in agriculture soil and food crops of Bangladesh.

Key words Arsenic .Ground Water. Food Chain. Bangladesh

Introduction

Arsenic is a common metaloid of the environment. It usually presents in a small amount in all rocks, soils, waters, air and biological tissues (Nriagu and Pacyna 1988; Matschullat 2000; Miteva et al. 2005). Arsenic naturally occurs as sulfides and as complex sulfides of iron, nickel, and cobalt. It is estimated that the global As production is 75,000 to 100,000 tons annually, of which the United States produces about 21,000 tons and uses about 44,000 tons. Sweden is the world largest As producer and importer in the world market (NAS 1977; EPA 1980).Recently, As is using for the production of herbicides, incesticides, desiccants, wood preservatives, and growth stimulants for plants and animals (Ali 2003). Arsenic is one of the most toxic elements of the environment (Cullen and Reimer 1989; Dermatas et al. 2004; Hudson-Edwards et al. 2004). Arsenic can enter terrestrial and aquatic environments through natural geologic processes and anthropogenic activities as well. So, arsenic can also present in ground-water and soil.

Groundwater is the main source of drinking water in most of the countries (Table 1). It is estimated that approximately one third of the world's population use groundwater for drinking purpose (UNEP 2000). According to WHO guideline, the maximum consumable limit of As in drinking water is 10 µg/L. However, Bangladesh and many developing countries still use the 50 µg/L of As in drinking water as standard (Table 2).In the 1990s, several studies detected As in groundwater (due to anthropogenic and non-anthropogenic activities) in different countries e.g. USA, Argentina, Taiwan, China, Hungary, Vietnam, India and Bangladesh (Smedley and Kinniburgh 2002, Anawar et al. 2003; Roychowdhury et al. 2002).

Table 1 Proportion of groundwater in drinking water supplies in selected countries

Country	Area (sq mile)	Population	Proportion of groundwater
Denmark	16,639	5,450,661	98%
Hungary	35,919	9,981,334	95%
Portugal	35,672	10,605,870	80%
Switzerland	15,942	7,523,934	83%
UK	94,525	60,609,153	28%
Spain	194,896	40,397,842	21%
Netherlands	16,033	16,491,461	68%
Bangladesh	55,598	147,356,352	90%
Finland	130,558	5,231,372	57%
France	211,208	60,876,136	56%
Greece	50,942	10,688,058	50%
Italy	116,305	58,133,509	80%
Germany	137,846	82,422,299	72%
Norway	125,181	4,610,820	13%
Czech Republic	30,450	10,235,455	43%

Table 2 Limits for As in drinking water (µg/L)

Organization/Country	Concentration of As	References
WHO	10	
EU	10	Matschullat 2000
Netherlands	10	
Germany	10	
Bangladesh	50	BGS & DPHE 2001

Bangladesh is a developing country with nearly 140 million people. About 82% of the population lives in rural areas. More than 80% of the population depends on agriculture for their livelihood. Now-a-days, 90% of Bangladeshi depends on ground water for drinking purpose because much of surface water of Bangladesh is microbially unsafe to drink. Before1960's, people usually used surface water (e.g. pond, lake and river) for drinking and domestic purposes but severe microbial diseases specially cholera were very common at that time. To mitigate that problem, in 1970's, the government with the assistance of UNICEF, WHO and many NGOs, drilled several million groundwater wells (BGS & DPHE, 2001).Besides domestic use, huge quantities of water from shallow aquifer are also using for irrigation during the dry season. Unfortunately, the vast area of Bangladesh's groundwater is naturally contaminated with arsenic (As) concentrations above the World Health Organization (WHO) drinking water guideline (0.01 mg/L) and even the Bangladeshi drinking water guideline (0.05 mg/L) (BGS and DPHE 2001; Smedley 2003; Anawara et al. 2002). Groundwater in the majority of wells in 60 of the 64 districts, covering approximately 118,000 sq km (nearly 80% of the country), has concentrations of arsenic exceeding the World Health Organization's limit of 10 µg/L (Table 3). Only 30% of groundwater contains arsenic at levels below the Bangladesh drinking-water standard.Concentrations of arsenic exceeding 1,000 µg/L in shallow tube-wells were reported from 17 districts in Bangladesh Agricultural soil and food grains are also being contaminated with As.Nearly, 80 million people of Bangladesh are in great risk with As contaminated water and food stuff.

The aim of this review is to provide an overview of the latest findings of As contamination in food materials through arsenic-contaminated irrigation-water and the subsequent transfer of arsenic via water/soil to crops. These findings would likely help the researchers and policy makers to conduct more research on this issue and formulate proper agricultural strategies to produce As free food products and to reduce the arsenic causing disease risk in human being.

Chemistry of As

The atomic number of As is 33, which is situated in Group 15 (or VA) of the periodic table. Arsenic may exists in four different oxidation states: (-III), (0), (III), and (V), however, oxidized As (III) and As(V) are the most widespread forms in nature. Arsenic ranks twentieth in abundance of elements in the earth's crust, fourteenth in seawater and is the twelfth most abundant element in the human body (Mandal and Suzuki 2002). The overall arsenic cycle is similar to the phosphate cycle.

Table 3 Arsenic concentration in natural surface water of different parts of the world

Location	Groundwater (mg/L)	River water (mg/L)	Lake water (mg/L)	References
Bangladesh	0.02-9.0	--	--	Bhattacharya et al. (2002)
Taiwan	0.01-1.82	--	--	Hossain (2006)
Norway	--	0.25 (<0.02-1.1)	--	Lenvik et al. (1978)
Belgium	--	0.75-3.8 up to 30	--	Andreae and Andreae (1989)
Maxico	0.5-3.7	--	--	Hossain (2006)
British Columbia	--	--	0.2-0.42	Azcue et al. (1994,1995)
Sweden	--	--	0.06-1.2	Reuther (1992)
Argentina	1.0-4.8	--	--	Bhattacharya et al. (2002)
China (Inner Mongolia)	0.5-18.60	--	--	Bhattacharya et al. (2002)
Cordoba,Argentina	--	0.07-1.14	--	Lerda and Prosperi (1996)
North chile	--	4.0-4.5	--	Sancha (1999)
Western USA	--	--	0.003-10.00	Benson and Spencer (1983)
Thailand (Ron Phibun)	--	0.04-5.83	--	Williams et al. (1996)

The reduced trivalent form of arsenic As (III), called arsenite, is normally found in anaerobic or reducing groundwater and the oxidized pentavalent form As (V), called arsenate, is found in surface water and aerobic groundwater(Pongratz 1998; Smith et al. 1998; Turpeinen et al. 1999, 2002). In some groundwater, both forms have been found together in the same water source. Arsenate exists in four forms in aqueous solution based on pH; H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$ and AsO_4^{3-}. Similarly arsenite exists in five forms; $H_4AsO_3^+$, H_3AsO_3, $H_2AsO_3^-$, $HAsO_3^{2-}$ and AsO_3^{3-} (Jonsson and Lundell 2004). Arsenic is sensitive to mobilisation at pH values typically found in groundwater, i.e. pH 6.5-8.5, and under both oxidising and reducing conditions (Smedley and Kinniburgh 2002).

Arsenic in ground water of Bangladesh

Arsenic exists in the form of As^{5+} in surface waters, and As^{3+} in ground waters. The residence time of arsenic is 60,000 years in the ocean and 45 years in a freshwater lake (NRCC 1978). The baseline concentration of arsenic in an uncontaminated river is usually very low, with a range from 0.1 to 0.8 µg/L but nomally does not exceed 2 µg /L (Seyler and Martin 1991). The main reasons responsible for the low concentration level of arsenic is the high affinity of arsenic to oxide minerals especially iron oxides/hydroxides.In addition to geochemical factors, microbial agents can influence the oxidation state of As in water, and can mediate the methylation of inorganic As to form organic As compounds. Microorganisms can oxidize arsenite to arsenate; reduce arsenate to arsenite or even arsine (AsH_3). Bacteria and fungi can reduce arsenate to volatile methylarsines.

Arsenic contamination in the ground water of Bangle-delta (Bangladesh and West Bengal, India) region was first discovered in 1980's in the West Bengal of India. The scientists of West Bengal urged Bangladesh to test the level of As in Bangladesh as both the regions (Bangladesh and West Bengal, India) are situated in the Bengal-delta. In 1993, the Department of Public Health Engineering first identified the presence of arsenic in well-water in three districts in the northwest region of Bangladesh.However, the major concern about the As contamination in Bangladesh's groundwater raised in 1998 when the first national survey of arsenic contamination in Bangladesh was undertaken by the Department of Public Health Engineering of Bangladesh, British Geological Survey and Department for International Development (DFID), UK. That survey indicated that arsenic contamination was concentrated in the shallow aquifers of up to 150m (roughly 500 ft) depth, although the highest average contamination was found in the 15-30m (50-100ft) range. The very shallow aquifer of below 15m (50ft) seemed to be largely arsenic free, although subsequent studies have shown significant arsenic contamination in shallow dug wells. However, the surface water of Bangladesh is uncontaminated with As.

A number of hypotheses have been developed to explain the origin and basic cause of As calamity in Bangladesh (BGS and DPHE 2001). However, the Pyrite hypothesis and Oxy-hydroxide reduction hypothesis are the most renowned among those. According to Dudas (1984) pyrite is known as a carrier of arsenic and may contain up to 5,600 mg/kg. Several studies (Das et al. 1984; Chatterjee et al. 1995) in West Bengal suggest that extensive seasonal pumping of groundwater for irrigation is responsible for As contamination in groundwater table. However, they did not showed any direct evidence to support the idea. Actually, this idea is based on the assumption that arsenic is present in the sulphide mineral pyrite and arsenopyrite. According to the theory, lowering of the water table due to pumping introduces oxygen into the water table, which causes the breakdown of pyrite and releases arsenic, iron and sulphate into the water. But the arsenic contaminated groundwater of Bangladesh typically shows very low concentrations of sulphate.

The Oxy-hydroxide reduction model came in 1997.According to this hypothesis As adsorbed on Fe-/Mn-oxides/ hydroxides is released into the groundwater due to a decrease of the redox state in the aquifer (Nickson et al. 1998 and 2000; Smedley and Kinniburgh

2002; Bhattacharya et al. 1997; Stuben et al. 2003). Again there is no adequate model to explain how the low and diffuse As contents in the aquifer sediments generated the high As concentrations in the groundwater and there are only speculations on the factors triggering the redox decrease.

Soil arsenic in Bangladesh

The concentrations of As in non-contaminated soils range from 0.1 to 10 mg/Kg (Kabata-Pendias and Pendias 1992). However, the As content in some parts of Bangladesh soils are more than 30 mg/kg. Several soil analytical works have been done on As issue in Bangladesh (Ahsan et al. 2008; Meragh and Rahman 2003; Hossain et al. 2001; Huq et al. 2003). The results of several studies on soil arsenic of different parts of Bangladesh are summarized in Table 4. In Srinagar thana, Bangladesh, arsenic concentration in the top soil layer (top 75 mm) of paddy field varied from about 7 to 27.5 mg/kg (Ali et al. 2003) whereas at the Sonargaon area of Bangladesh arsenic concentration in the top soil layer of paddy field varied from about 3.2 to 19 mg/kg. Das et al. (2004) reported that the mean arsenic concentration in soils of two up-zillas (Daudkandi and Begumganj) of Bangladesh was 15.676 ppm which was 1.5 times higher than the worldwide natural concentration of 10 ppm. However, arsenic contents in soil differ in different locations. Ahsan et al. (2008) reports high level of soil As (33.15 mg/kg) in Faridpur of Bangladesh and ground water of this region is also contain high level of As. On the other hand, in Dhamrai region (area with low As in groundwater) the level is soil As is 6.10 mg/kg which is lower than world limit (Ahsan et al. 2008).

Factors affecting As mobility in soil

The mobility of As in water and soil depends on several factors like pH, redox conditions, biological activity and adsorption-desorption process (Ali 2003; Goh and Lim 2005).So, the presence of high concentrations of As in soil is not only dependent on the concentration of As in soils but also on the aforesaid factors. Moreover, organic content, soil fractions and oxides of Al, Fe and Mn also affect the amount of As in soil. Several studies have reported the mobilization and attenuation of As in the fine and coarse soil fractions (Lombi et al. 2000; Bhattacharya et al. 2002; Cai et al. 2002; Sadiq 1997). Sediments with finer texture usually contain more arsenic than sediments with coarser texture (Khan 2003). According to Lombi et al. (2000), the coarse textured soils are likely to yield a higher fraction of readily mobile As, while As in the fine textured soils is relatively immobile, but can be released upon changes in the subsurface geochemical environment. Climate and geomorphic characteristics of an area, such as rainfall, surface runoff, rate of infiltration, and the groundwater level and its fluctuations, also affect the mobility and redistribution of arsenic (Bhattacharya et al. 2002).

Redox potential is also the most important factors controlling As speciation (Smedley and Kinniburgh 2002). The term redox represents a large number of chemical reactions involving electron transfer. When a substance is oxidised, it transfers electrons to another substance, which is then reduced. The point at which a given reaction can take place is determined by the electrical potential difference or redox potential (Eh) (Swedish EPA 1999). This redox sequence is of extreme importance on arsenic speciation, not only because it is an indication of redox level that the arsenic resides on but also because it influences the behaviours of the important bulk elements (iron and sulphur), which have very strong binding affinity to arsenic and are principally responsible for the enhanced contamination of arsenic in the environment. Redox processes can be mediated by microorganisms, especially bacteria which serve as catalysts in speeding up the reactions. Mobility of As in natural system also largely depends on adsorption and desorption processes. Both arsenate and arsenite adsorb to surfaces of many different solids including iron, aluminium and manganese oxides, as well as clay minerals. Arsenate is much more strongly adsorbed than arsenite because of its greater negative charge at the same pH (Ali and Ahmed 2003).

Fe-oxides/hydroxides represent the major sink for As adsorption in soils, whereas the importance of Al- and Ca-bound fractions are variable (Ali and Ahmed 2003; Chen et al. 2002, Akins and Lewis 1976; Wasay et al. 2000; Manning and Goldberg 1997). Fixation of As with iron oxide surfaces is an important reaction in the subsurface soil because iron oxides are widespread in the environment as coatings on other solids, and because arsenate adsorbs strongly to iron oxide surfaces in acidic and near-neutral pH conditions.Soil organic matter has no contribute in significant quantities to As sorption in soils, especially in the presence of effective sorbents such as hydrous Fe oxides (Livesey and Huang 1981; Wenzel et al. 2002). However, a few researches have been designed on As adsorption by organic matter (Fitz and Wenzel 2002).

Table 4 Arsenic concentration of soil in different locations of Bangladesh

Location	As content (mg/kg)	References
Barisal	26.1	
Ramgati	16.8	Meragh and Rahman (2003)
Burichang	18.4	
Chandina	6.8	
Dhamrai	6.10	Ahsan et al.(2008)
Faridpur	33.15	
Mirsharai	6.5	
Pahartali	7.0	Meragh and Rahman (2003)
Rawjan	8.6	
Belabo	14.6	
Sirajdikhan	4.930	
Chandina	3.321	Huq et al. 2003
Sonargoan	9.915	
Ghatail	16.5	
Sonatala	13.4	
Kendua	9.0	Meragh and Rahman (2003)
Tarakanda	9.3	
Melandaha	9.6	
Dumuria	21	
Ishurdi	33.3	
Bhabanipur	1.783	
Kalapur	0.594	
Bhabanipur	1.783	Hossain et al. 2001
Sherpur	2.576	
Srimongal	1.981	
Khulna	5.13	
Meherpur	4.68	Uddin,1998
Pabna	7.60	
Polashbari	7.6	
Pirgacha	12.4	Meragh and Rahman (2003)
Bhabanipur	24.3	
Atwari	8.1	
Khulna	5.13	
Meherpur	4.68	
Pabna	7.60	
Laksam	2.68	Uddin 1998
Gazipur	3.13	
Rajshahi	3.80	
Comilla	5.64	Das et al.2004
Chapainabganj	56.68	Alam& Sattar 2000

Transmission of As in agricultural soil through irrigating water

The immediate and long-term impact of using As contaminated water for irrigating paddy soils is a burning concern as arsenic can transfer from water to soil and several studies have proven this phenomenon. Boro (dry season) rice requires approximately 1000 mm of irrigation water per season. Meharg and Rahman (2003) predicted that soil arsenic levels could be raised by 1 µg/g per annum due to irrigation with As contaminated water. Alam and Sattar (2000) showed that arsenic contained in soils was positively correlated with arsenic content in water. The study of Ahsan et al. (2008) reported that As rich irrigation water can enrich the As level in agricultural soil up to five time than the normal soil. In the unaffected areas, where irrigation water contained little As (< 1 µg/L), As concentrations of rice field soils ranged from 1.5 to 3.0 mg/kg whereas the agricultural soil contains arsenic up to 436 µg/L where irrigated with As rich ground (Saha and Ali 2007). Some recent studies (Dittmar et al. 2007) show that input of As into rice field soils decreases significantly with increasing distance from the irrigation water inlet. However, there is a tendency of soil build-up of As in some cases where As-contaminated ground water is used for irrigation (Table 5)

Arsenic in food materials

Arsenic is not an essential element both for plant and animal. Food crops such as vegetables and cereals can become a path by which As may enter the food chain, because they can reflect the levels of As that exist in the environment in which they are cultivated (soil and irrigation water). So, the accumulation of As in rice field soil and its introduction into the food chain through uptake by the rice plant is of major concern. The accumulation of arsenic in plants occurs primarily through the root system and the highest arsenic concentrations have been reported in plant roots and tubers (Anastasia and Kender 1973; Marin et al. 2003). Therefore, tuber crops are expected to have higher arsenic contents than that of other crops when those are grown in arsenic contaminated soil.

Arsenic in rice

Rice is the staple food for Bangladeshi people. There are two seasons for rice culture; aman and boro. Aman culture period is in rainy season when no irrigation is required but the boro cultivation phase (in dry season) is completely depended on irrigation. About 86% of total groundwater withdrawn in Bangladesh is utilized in agricultural sector especially in rice cultivation in dry season. A total of 925,152 shallow and 24,718 deep tube-wells were used for irrigation during the 2004 dry season (BADC 2005) and groundwater irrigation covered about 75% of the total irrigated area. Boro cultivation and irrigation have together increased since 1970. Saha (2007) estimated that nearly 1000 metric tons of As is cycled with irrigation water during the dry season of each year as boro rice needs huge amount of water.

Table 5 Arsenic in water and corresponding As in soils in some parts of Bangladesh

Location	Water As (mg/L)	Soil As (mg/kg)	References
Chapainawabganj Sadar	0.01-0.056	1.27-31.84	Alam and Sattar 2000
Kustia Sadar	0.01-0.07	7.01-24.20	
Bera	0.01-0.056	16.56-22.29	
Ishurdi	0.01-0.41	1.27-24.20	
Sarishabari	0.025-0.071	3.18-10.83	
Gopalganj Sadar	0.015-0.079	0.26-7.03	Farid et al. 2003
Mukshidpur	0.012-0.05	0.30-8.62	
Monirampur	0. 024-0.076	0.69-4.96	
Pirghacha	0.013-0.066	1.2-8.1	
Rajarhat	0.01-0.049	0.20-5.5	
Chapi Nawabganj Sadar	0.05-0.079	1.9-7.4	
Charghat	0.015-0.068	0.20-40.08	
Sharsha	0.041	13.670	Huq et al. 2003
Sirjdikhan	0.544	10.655	
Alamdanga	0.058	10.675	
Meherepur	0.016	28.220	
Laksham	0.145	10.791	
Sonargaon	0.860	14.00	
Bancharampur	0.092	17.147	
Nagarkanda	0.064	26.559	

It is expected that surface soil of agricultural land accumulates arsenic from contaminated water due to its high affinity with metal oxides/hydroxides in soil. Some studies (Alam and Sattar 2000; Meharg and Rahman 2003) have reported elevated concentrations of As in rice field soils irrigated with As contaminated groundwater. The study of (Williams et al. 2006) showed that rice obtained from districts with contaminated waters (>50 µg/L) were clearly more elevated with As than rice from less contaminated or uncontaminated (<50 µg/L) districts and boro season rice contained more As than aman season rice (Table 6).

Duxbury et al. (2002) found that arsenic concentrations in rice could varied from 10 - 420 µg/kg in dry condition. On the other hand, the studies of Das et al. (2004) and Abedin et al. (2002) showed that no samples of rice grain had arsenic concentrations more than the recommended limit of 1.0 mg/kg in three different regions of Bangladesh. However, arsenic accumulation of rice grain depends on the variety of rice (Table 7). A high level of As in rice grain (ranging between 1.75 and 1.83 mg/Kg) of Nawabgonj and Naogoan (high level of As in paddy soil) has been reported by Meragh and Rahman (2003). So, the order of magnitude of As concentration in rice grain related with the magnitude of As concentration in soil and variety of rice species. It is also important to point out that the results of Meragh and Rahman (2003) also higher than the results of other researches of the world as well. As for instance, the field trials by Xie and Huang (1998) on Chinese arsenic polluted paddy soils showed that rice could accumulate up to 0.725 mg/kg dry wt arsenic when grown on soils containing 68 mg/ kg arsenic. In Taiwan, the field survey showed that rice grain grown on paddy soils containing 6.9-7.5 mg/kg of arsenic had an arsenic concentration of 0.2 mg/kg dry weight (Schoof et al. 1999).

Table 6 Arsenic level in ground water and rice grain in different districts of Bangladesh (Williams et al. 2006)

District	Aman season rice (µg/g;dry wt)		Boro season rice (µg/g;dry wt)		As in groundwater (µg/L)
	Min-max	Mean	Min-max	Mean	
Barisal	0.10-0.32	0.16 ± 0.01	0.17-0.44	0.25 ± 0.06	92
Bogra	0.10-0.22	0.14±0.02	0.13-0.17	0.15±0.02	18
Brahmanbaria	0.15-0.31	0.22±0.04	0.21-0.31	0.26±0.03	101
Chandpur	0.13-0.40	0.22±0.02	0.04-0.91	0.28±0.09	366
Chuadanga	0.10-0.48	0.24±0.05	0.15-0.81	0.32±0.03	79
Dhaka	0.09-0.15	0.11±0.02	0.12-0.23	0.18±0.03	41
Dinajpur	0.06-0.11	0.08±0.01	0.13-0.17	0.15±0.01	3
Fardipur			0.44-0.58	0.51±0.07	140
Khulna	0.04-0.32	0.12±0.01	0.14-0.20	0.17±0.02	35
Kushtia	0.07-0.28	0.19±0.06	0.12-0.23	0.18±0.01	104
Meherpur	0.06-0.42	0.18±0.02	0.15-0.84	0.29±0.04	116
Mymenshing	0.04-0.18	0.11±0.01	0.21-0.36	0.26±0.05	25
Nator	0.08-0.18	0.12±0.01	0.11-0.20	0.17±0.02	45
Satkhira	0.08-0.92	0.36±0.04	0.19-0.62	0.38±0.03	133
Sherpur	0.07-0.13	0.12±0.01	0.13-0.23	0.17±0.02	22

Table 7 Arsenic content of irrigation water, soil, different parts of rice plants in Bangladesh (Alam and Rahman 2003)

As in water (ppb)	As in soil (mg/kg)	Rice variety	As in rice grain (mg/kg)
156	7.52	BR-14	0.00
364	2.07	BR-14	0.00
277	12.0	BR-14	0.00
199	3.76	BR-28	0.00
131	3.98	BR-28	0.032
188	3.30	BR-28	0.00
255	2.42	BR-28	0.063
62	2.01	BR-29	0.016
208	3.63	BR-29	0.00
278	9.93	IR-50	0.00
105	3.37	Purbachi	0.022
222	2.24	Purbachi	0.026
177	3.02	Purbachi	0.094

It appears that arsenic present in irrigation water and soil results in higher level of arsenic in rice plant root, leaf and stem (Ali 2003). A very recent study of Liu et al. (2005) on the distribution of As in rice plant showed that the order of As accumulation in rice plant was in the order root > leaf > grain and they detected the level of As up to 248±65 mg /kg in root tissue where as 1.25±0.23 mg /kg was detected in the grain. The root, shoot and leaf tissue of rice plant contain mainly inorganic As III and As V while the rice grain contain predominantly DMA (85 to 94%) and As III (Liu et al. 2005). Tsutsumi et al. (1980)

reported 149 mg of As/ kg dry weight in rice straw when soil arsenic concentration was 313 mg /kg. Abedin et al. (2002) conducted a study in greenhouse and found 25 mg of As /kg dry weight in rice straw when the plant was irrigated with As rich water (2mg /L).

So, it can be predicted that As contaminated irrigation water could easily increase the As level in rice grain, straw and other part of rice plant. Arsenic contents in boro rice could be 1.3 times higher than for aman rice (Table 6). However, accumulation of As by rice largely depends on redox potential in plant and soil phosphate concentration, rhizosphere iron plaque formation, microbial activity, and rice variety (Meragh 2004). The precise mechanisms controlling the translocation of As to grain is yet to be determined.

Soil As is also responsible for the reduction of rice production. Arsenic concentration in irrigation water (0.1 to 2.0 mg/L) and soil (5 to 50 mg/kg) could result in lower yield of a local rice variety. Rice production is reported to decrease by 10% at a concentration of 25 mg/kg As in soil (Xiong et al. 1987). Abedin et al. (2002) reported the reduced yield of a local variety of rice (BR-11) irrigated with elevated As (0.2 to 8.0 mg/L) bearing water.

Arsenic in vegetables

Several greenhouse studies show that an increment in As in cultivated soils leads to an increment in the levels of As in edible vegetables (Burlo et al. 1999; Carbonell-Barrachina et al. 1999). In Bangladesh, a few studies have been carried out to analyse the amount of As in different types of vegetables. Farid et al. (2003) conducted a study on level of arsenic in different types of vegetables cultivated with As free and As contaminated ground-water in Bangladesh and the results of that study is presented in Table 8. They found that the level of arsenic was higher in vegetables which were irrigated with arsenic contaminated water.

Ali et al. (2003) conducted a research on As concentration in different vegetables which were irrigated with low level of As rich pond water. They found the highest accumulation of arsenic in the root of potato plants (up to 2.9 mg/kg) whereas As concentration in the edible parts varied from 0.12 to 0.85 mg/kg. Study results of Ali et al. (2003) also showed that As concentration in edible parts of lalshak (spinach) ranged from < 0.39 to 0.96 mg/kg; for datashak (spinach) it ranged from 0.56 to 1.06 mg/kg, for cabbage 0.38 to 1.6 mg/kg and for cauliflower 0.35 mg/kg. Das et al. (2004) also conducted a research on vegetables cultivated with As rich ground water in Bangladesh. Their result revealed that the mean arsenic concentrations in potatoes (*Solanum tuberosum*) and pointed gourd/potals (*Trichosanthes dioeca*) were 0.598 and 0.10 ppm FW, respectively and were higher than the values for those grown on uncontaminated soils, as reported in literature (Nriagu, 1994). Significant levels of arsenic in arum/kachu (*Colocasia antiquorum*) and water spinach/kalmi sak (*Ipomoea reptans*) were found (range: 0.11-3.49 ppm FW) and (range: 0.09-2.03 ppm FW) respectively. Arsenic concentrations in balsam apple/korola (*Momordica charantia*), ladies finger/derosh (*Hibiscus esculentus*), and jute (*Corchorus capsularis*) leaves were not significant. High level of arsenic was found in sajnay danta (*Amaranthus lividus*) stem (1.41 ppm FW).Study of Alam et al. (2003) found mean As concentrations (mg/kg) were in snake gourd (0.489), ghotkol (0.446), taro (0.440), green papaya (0.389), elephant foot (0.338) and Bottle ground leaf (0.306), respectively. So, tuber crops are expected to have higher arsenic contents than that of other crops when those are grown in arsenic contaminated soil as root system is the main parts of accumulate As in plants.

Table 8 Arsenic content in vegetables of Bangladesh (Farid et al. 2003)

Crop	Location	Arsenic content (ppm)			
		Contaminated		Uncontaminated	
		Range	Mean	Range	Mean
Tomato	Nawabgonj	0.016-0.049	0.030	0.001-0.025	0.011
	Monirampur	0.013-0.021	0.017	0.001-0.014	0.007
Potato	Pirgacha	0.042-0.107	0.068	0.024-0.068	0.041
	Rajarhat	0.00-0.080	0.024	0.00-0.055	0.021
Brinjal	Nawabgonj	0.042-0.063	0.049	0.028-0.063	0.045
Cabbage	Muksedpur	0.031-0.042	0.037	0.00-0.059	0.030
Okra	Charghat	0.034-0.046	0.040	0.016-0.046	0.031
Amaranth	Nawabgonj	0.093-0.201	0.161	0.099-0.109	0.103
	Pirgacha	0.182-0.79	0.935	0.060-0.370	0.241
Spinach	Monirampur	0.132-0.606	0.321	0.072-0.240	0.163

Arsenic in fish

A very limited studies have been carried out in Bangladesh to find out the As concentration in fish in Bangladesh. Das et al. (2004) analyzed arsenic content in catfish (*Heteropenuestis fossilis*) (0.021-0.043 ppm) from an uncontaminated canal of Bangladesh and did not found no significant level of arsenic in the fish tissues. Lata fish (*Ophicephalus punctatus*) did not contain unacceptable levels of arsenic from three different regions of Bangladesh.

Discussion

Bangladesh is an agricultural country. Rice, fish and vegetables are the main food stuffs of the people. The present review indicates that As is gradually interring into the food chain through As contaminated irrigated water and soil. To mitigate the huge food demand, groundwater is using for irrigation for paddy culture and horticulture during the dry season. The water demand of rice is very high. The volume of water used for irrigation of Boro rice in the Indo-Gangetic Plain is in the range between 1000 and 1800 mm/year (Huq et al. 2003). Norra et al.(2005) reported As content in the soils of the agricultural areas irrigated with As bearing groundwater, up to five times higher than the background values of the reference site. Although, As concentration of rice field soils increases significantly at the end of the irrigation season, it decreases subsequently during the wet season, possibly as a result of remobilization of As due to reductive dissolution of As bearing iron oxyhydroxides. The remobilized As may be leached into deeper soil layers and/or transported away from the field with the flood/rain water. However, data on accumulation of arsenic on irrigated agricultural soil over time is not available. Also, there appears to be a lack of information on desorption kinetics of arsenic from soil, which is needed for better understanding of the long-term retention of arsenic on soil. More studies should be carried out to better understand the processes leading to the depletion of As in rice field soil during the wet season and desorption kinetics process of arsenic from soil.

Rice plants and vegetables are also accumulating As from contaminated soil. The high As contents measured in the root are due to an Fe-rich mineral plaque which coats the root. Though several studies indicated that the concentration of arsenic in edible parts of most plants is generally low but long term ingestion of As contaminated rice and vegetables could be dangerous for human health. The average daily rice consumption by an adult in Bangladesh is between 400 and 650 g raw rice grain (Duxbury et al. 2002). Schoof et al. (1999) reported that between 30% and 85% of arsenic in rice is inorganic. So, intake of arsenic from rice and its potential impact on human exposure should not be neglected. Use of contaminated groundwater for drinking and cooking may enhance the overall situation. As a result, several researches are also essential for the clarification of As intake through cooked rice, cereal and solid food stuffs prepared by arsenic contaminated water. It is also necessary to invent arsenic tolerant rice varieties which will not accumulate As. Variation in arsenic tolerance and iron plaque formation could be the starting points for breeding rice for arsenic affected soils (Meharg 2004). Involvement of high yield variety of rice which need very low amount of water would be one of the good solutions.

Arsenic could also be accumulated by freshwater fish, marine fish and birds. Sea fish and shell fish may contain significant amount of As in their muscle and liver tissue. Lima et al. (1984) found significant level of As (> 0.1 mg/Kg ww) in muscle of different sea fish and shell fish like dogfish, rays, sole etc. However, no research has been conducted in Bangladesh to find out the As status in marine fish and shell fish and other organisms. More over, in Bangladesh people like to take dried sea fish but As concentration becomes higher (up to 5 times from fresh fish concentration) in dry condition (Lima et al. 1984). Unfortunately, a very few research has conducted to ascertain the effect of As in aquatic biota, fish and bird in Bangladesh.

Cattle are one of the primary consumers of terrestrial ecosystem. In Bangladesh, cattle generally feed on rice straw and husk as there is a severe scarcity of grassing land due to high population. Cattle also drink As contaminated water and the people even cannot imagine to provide the arsenic free water to the cattle as arsenic free drinking water is not very easy to get even for human consumption in some part of the country. It has been mentioned that high level of As was determined in the rice husk by several studies. Rice straw is not consumed as human diet but rice straw trash is commonly fed to cattle. Though, there is no direct report of arsenic accumulation in cattle body from rice straw or husk, the consequence of exposure to this toxic element in organs such as the liver and kidneys of this animal is well reported (WHO 2001). Moreover, there is no available data on the level As in milk and cattle meet. So, there is no clear information whether the cattle have been infected by As and cattle meet and milk transferring As to human body. Further research in this area is needed to quantify the importance of As transportation to human being through soil-plant-animal-human pathway.

Accumulation of As from one tropic level to other tropic level depends not only on the total As concentration but also largely depends on the bioavailability. So, one area with high As concentration may not be dangerous in comparison to another area with lowest As concentration. However, a very few research has been designed to find out the bioavailability of As from soil and water to food chain in Bangladesh. More over no study yet to conduct to determine the ecological risk of As and other metals in Bangladesh. It should be considered that a very little is known about the chemical forms of arsenic (e.g., inorganic and organic) in crop/vegetable/fish, which in turn is needed for estimating its toxicity. More researches are essential to ascertain the chemical forms of arsenic (e.g., inorganic and organic) in crop/vegetable and the bioavailability of As in crop and vegetables. Studies with the larger samples are needed to demonstrate the extent of arsenic contamination of food in Bangladesh. So, immediate researches are essential to ascertain the impact of As and other metals in over all food chain and ecosystem of Bangladesh.

Human being can also uptake As from contaminated rice, vegetables, milk and meet hence ‘‘plant–human’’ and ‘‘plant–animal–human’’ could be other potential food chain pathways of arsenic accumulation in human body (Fig.1).

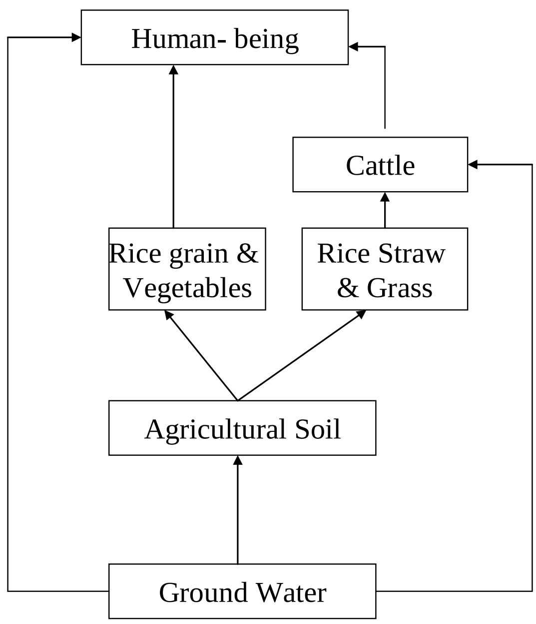


Fig.1 Possible routes of As exposure to human-being in Bangladesh

There is no system in Bangladesh to check the level of As in food grain as the country is poor and with deficit in food. From this review, it could be perceived that arsenic contaminated drinking water is not the only source of As accumulation in human body. This study also wants to point out that the people who live in As contaminated regions are not only at risk but also other people (who live in non-contaminated zones) are in danger as they are also consuming arsenic contaminated food stuffs.

References

Abedin MJ, Malcolm S, Andy A, Cotter-Howells J (2002) Arsenic Accumulation and Metabolism in Rice (*Oryza sativa*). Environ Sci Technol 36: 962 -968

Ahsan DA, DelValls AC, Blasco J (2008) Distribution of Arsenic and Trace Metals in the Floodplain Agricultural Soil of Bangladesh. Bull Environ Contam Toxico (Accepted)

Akins MB, Lewis RJ (1976) Chemical distribution and gaseous evolution of arsenic-74 added to soils as DSMA- 74As. Soil Sci Am J 40: 655- 658

Ali M (2003) Review of Drilling and Tubewell Technology for Groundwater Irrigation. The University Press Limited, Dhaka, Bangladesh

Ali MA, Ahmed MF (2003) Environmental Chemistry of Arsenic. In: Ahmed MF (ed) Arsenic contamination: Bangladesh Perspective. ITN-Bangladesh, Dhaka

Ali MA, Badruzzaman ABM, Jalil MA, Hossain MD, Ahmed MF, Masud AA, Kamruzzaman M, Rahman MA (2003) Arsenic in plant-soil environment in Bangladesh. In: Ahmed MF, Ali MA, Adeel Z (eds) Fate of frsenic in the environment. Proceedings of the international symposium on fate of arsenic in the environment, ITN Centre, BUET, Dhaka

Alam MB , Sattar MA (2000) Assessment of arsenic contamination in soils and waters in some areas of Bangladesh. Water Sci Technology 42:185-193

Alam MGM, Snow ET, Tanaka A (2003) Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. Sci Total Environ 308: 83-96

Alam , Rahman (2003) Accumulation of arsenic in rice plant from arsenic contaminated irrigation water and effect on nutrient content. In: Ahmed MF, Ali MA, Adeel Z (eds) Fate of frsenic in the environment. Proceedings of the international symposium on fate of arsenic in the environment, ITN Centre, BUET, Dhaka

Anawar HM, Akai J, Komaki K, Terao H, Yoshioka T, Ishizuka T, Safiullah S, Kato K (2003) Geochemical occurrence of arsenic in groundwater of Bangladesh: sources and mobilization processes. J Geochem Explor 77:109– 131

Anastasia FB, Kender WJ (1973) The influence of soil arsenic on the growth of low-berry bush. Environ Qual 2: 335–337

Andreae MO, Andreae TW (1989) Dissolved arsenic species in the Schelde estuary and watershed, Belgium. Estuar Coast Shelf Sci 29: 421-433

Azcue JM, Murdoch A, Rosa F, Hall GEM (1994) The effects of abandoned gold mine tailing on the arsenic concentrations in water and sediments of Jack of Clubs Lake, BC. Environ Technol 15: 669-678

Azcue JM, Murdoch , Rosa F, Hall GEM, Jackson TA, Reynoldson T (1995) Trace element in water, sediments, pore water, and biota polluted by tailings from an abandoned gold mine in British Columbia, Canada. J Geo-chem Explor 52:25-34

BADC (Bangladesh Agricultural Development Corporation) (2003) Survey report on irrigation equipment and irrigated area in boro/2003 season. Survey and monitoring project for development of minor irrigation; BADC: Sech Bhaban, Dhaka, Bangladesh

Benson LV , Spencer RJ (1983) A hydro chemical Reconnaissance Study of the Walker River Basin, California and Nevada. USGS United States Geological Survey, Open File Report no 83-740

Bhattacharya P, Chatterjee D, Jacks G (1997) Occurrence of arsenic contaminated groundwater in alluvial aquifers from Delta Plains, Eastern India: Options for safe drinking water supply. Int J Water Res Manage 13:79-92

Bhattacharya P,Jacks G, Frisbie SH, Smith E, Naidu R, Sarkar B (2002) Arsenic in the environment: a global perspective. In : Sarker B (ed) Handbook of heavy metals in the environment , Marcel Dekker Inc, New York, pp. 147-215

BGS and DPHE (2001) Arsenic contamination of groundwater in Bangladesh. BGS Technical Report WC/00/19, British Geological Survey,UK

Burlo F, Guijarro I, Carbonell-Barrachina, AA, Valero D, Martínez-Sánchez F (1999) Arsenic species: effects on and accumulation by tomato plants. J Agric Food Chem 47:1247-1253

Cai Y, Cabrera JC, Georgiadis M, Jayachandran K (2002) Assessment of arsenic mobility in the soils of some golf courses in South Florida. Sci Total Environ 291:123-134

Carbonell-Barrachina AA, Burlo F, Valero D, Lopez E, Martinez-Romero D , Martinez-Sanchez F (1999) Arsenic toxicity and accumulation in turnip as affected by arsenical chemical speciation. J Agric Food Chem 47:2288-2294

Chatterjee A., Das D, Mandal BK, Chowdhury T R, Samanta G, Chakraborti D (1995) Arsenic in groundwater of six districts of West Bengal: the biggest arsenic calamity in the world. Part 1. Arsenic species in drinking water and urine of affected people. Analyst 120: 640-650

Chen M, Ma L., Harris WG (2002) Arsenic concentrations in Florida surface soils: influence of soil type and properties. Soil Sci Soc Am J 66: 632-640

Cullen WR, Reimer K J (1989) Arsenic speciation in the environment. Chem Rev 89: 713-764

Das, HK, Mitra AK, Sengupta PK, Hossain A, Islam F, Rabbani GH (2004) Arsenic concentrations in rice, vegetables and fish in Bangladesh: a preliminary study. Environ Inter 30: 383-387

Dermatas D ,Moon DH ,Menounou N, Meng X, Hires R (2004) An evaluation of arsenic release from monolithic solids using a modified semi-dynamic leaching test. J Hazardous Materials 116: 25-38

Dittmar J, Voegelin A,Roberts L C, Hug S J, Saha G C, Ali M A, Badruzzaman B M, Kretzschmar R (2007) Spatial distribution and temporal variability of arsenic in irrigated rice fields in Bangladesh. 2. Paddy soil. Environ Sci Technol 41: 5967–5972

Dudas M J (1984) Enriched levels of arsenic in post-active acid sulfate soils in Alberta. Soil Sci Soc Am J 48:1451-1452

Duxbury JM, Mayer A B, Lauren JG , Hassan N (2002) Arsenic content of rice in Bangladesh and impacts on rice productivity. Proceedings of 4th annual conference on arsenic contamination in groundwater in Bangladesh, Dhaka, Bangladesh

EPA. (1980) Ambient water quality criteria for arsenic. US Environ Protection Agency Rep 440/5-80-021, 205

Farid ATM, Roy KC, Hossain KM ,Sen R (2003)A study of arsenic contaminated irrigation water and its carried over effect on vegetable. In: Ahmed MF, Ali MA, Adeel Z (eds) Fate of arsenic in the environment. Proceedings of the international symposium on fate of arsenic in the environment, ITN Centre, BUET, Dhaka

Fitz WJ, Wenzel WW (2002) Arsenic transformations in the soil rhizosphere-plant system: fundamentals and potential application to phytoremediation. J Biotechnology 99: 259-278

Goh KH ,Lim T T (2005) Arsenic fractionation in a fine soil fraction and influence of various anions on its mobility in the subsurface environment. Appl Geochemistry 20: 229-239

Hossain MF (2006) Arsenic contamination in Bangladesh—an overview. Agri Ecosystem Env113:1-16

Hossain MM ,Sattar MA, Hashem MA ,Islam MR (2001) Arsenic status at different depths in some soil of Bangladesh. J Biological Sci1:1116-1119

Hudson-Edwards KA , Houghton SL, Osborn A (2004) Extraction and analysis of arsenic in soils and sediments. Trends Analy Chem 23: 745-752

Huq SMI, Rahman A, Sultana N, Naidu R (2003) Extent and severity of arsenic contamination in soils of Bangladesh. In: Ahmed MF, Ali MA, Adeel Z (eds) Fate of arsenic in the environment. Proceedings of the international symposium on fate of arsenic in the environment, ITN Centre, BUET, Dhaka

Jonsson L, Lundell L (2004) Targeting safe aquifers in regions with arsenic-rich groundwater in Bangladesh case-study in Matlab Upazila. Ms Thesis, Department of Earth Sciences, Uppsala University Uppsala, Sweden

Kabata-Pendias A , Pendias H (1992) Trace elements ion soils and plants. 2nd edn. CRC Press, Boca Raton, USA

Khan AA (2003) The aspects of Arsenic in Groundwater in Reference to the Bengal Delta. In: Ahmed M. F. (ed) Arsenic Contamination: Bangladesh Perspective. ITN-Bangladesh, Dhaka

Lenvik K, Steinnes E, Pappas AC (1978) Contents of some heavy metals in Norwegian rivers. Nord Hydrol 9: 197-206

Lerda DE, Prosperi CH (1996) Water mutagenicity and toxicology in Rio Tercero, Cordoba, Argentina. Water Res 30: 819-824

Lima AR, Curtis, Hammermeister DE, Markee TP, Northcott CE, Brooke LT (1984) Acute and chronic toxicities of arsenic (III) to fathead minnows, flagfish, daphnids, and an amphipod. Arch Environ Contam Toxicol 13:595-601

Livesey NT, Huang PM (1981) Adsorption of Arsenate by soils and its relation to selected chemical properties and anions. Soil Sci 131: 88-94

Liu W J, Zhu YG, Smith FA (2005) Effects of iron and manganese plaques on arsenic uptake by rice seedlings (*Oryza sativa*) Grown in solution culture supplied with arsenate and arsenite. Plant and Soil 277: 127-138

Lombi E, Sletten R S, Wenzel W W (2000) Sequentially extracted arsenic from different size fractions of contaminated soils. Water Air Soil Pollut 124: 319-332

Matschullat J (2000) Arsenic in the geosphere – A review. Sci Total Environ 249: 297-312

Mandal BK, Suzuki KT (2002) Arsenic round the world: A review. Talanta 58: 201-235

Manning BA, Goldberg S (1997) Arsenic (III) and arsenic (V) adsorption on three California soils. Soil Sci 162: 886-895

Marin AR, Masscheleyn PH, Patrick Jr (2003) Soil redox-pH stability of arsenic species and its influence on arsenic uptake by rice. Plant Soil 152: 245–253

Meharg AA (2004) Arsenic in rice – understanding a new disaster for South-East Asia. Trends in Plant Science 9 :415-417

Meharg A A, Rahman M (2003) Arsenic contamination of Bangladesh paddy field soils: Implications for rice contribution to arsenic consumption. Environ Sci Technol 37: 229-234

NAS (1977) Arsenic. Natl Acad Sci, Washington, DC, pp 332

Nickson RT, McArthur JM, Burgess W, Ahmed M, Ravenscroft P, Rahman M (1998) Arsenic poisoning of groundwater in Bangladesh. Nature 395: 338

Nickson RT, McArthur JM, Ravenscroft P, Burgess W, Ahmed KM (2000) Mechanism of arsenic release to groundwater, Bangladesh and West Bengal. Appl Geochem 15: 403–413

Norra S, Berner ZA, Agarwala P, Wagner F, Chandrasekharam D , Stuben D (2005) Impact of irrigation with As rich groundwater on soil and crops: A geochemical case study in West Bengal Delta Plain, India. Appl Geochemistry 20 : 1890–1906

NRCC (1978) Effects of arsenic in the Canadian environment. Natl Res Coun Canada Publ no. NRCC 15391, pp 349

Nriagu JO, Pacyna JM (1988) Quantitative assessment of worldwide contamination of air, water and soils by trace metals. Nature 133:134-139

Pongratz R (1998) Arsenic speciation in environmental samples of contaminated soil. Sci Total Environ 224: 133-140

Reuther R (1992) Geo-chemical mobility of arsenic in a flow-through water-sediment system. Environ Technol 13: 813-823

Roychowdhury T, Uchino T, Tokunaga H, Ando M (2002) Survey of arsenic in food composites from arsenic affected area of West Bengal, India. Food Chem Toxicol 40:1611–1621

Sadiq M (1997) Arsenic chemistry in soils: an overview of thermodynamic predictions and field observations. Water Air Soil Pollut 93: 117-136

Saha GC, Ali MA (2007) Dynamics of arsenic in agricultural soils irrigated with arsenic contaminated groundwater in Bangladesh. Sci Total Env 379: 180–189

Sancha AM (1999) Full- scale application of coagulation processes for arsenic removal in Chile: a successful case study. In: Chappell WR, Abernathy CO, Calderon RL (eds.) Arsenic exposure and health effects. Elservier Amsterdam, 87-96

Schoof RA, Yost LJ, Eickhoff J, Crecelius EA, Cragin DW, Meacher DM, Menzel DM (1999) A market basket survey of inorganic arsenic in food. Food Chem Toxicol 37: 839–846

Seyler P, Martin JM (1991) Arsenic and selenium in a pristine river-estuarine system: the Krka, Yugoslavia. Mar Chem 2: 277-294

Smedley PL , Kinniburgh DG (2002) A review of the source, behaviour and distribution of arsenic in natural waters. Appl Geochemistry17: 517-568

Smedley PL (2003) Arsenic in groundwater – South and East Asia. In: Welch AH, Stollenwerck KG (eds). Arsenic in Groundwater.Geochemistry and Occurrence. Dordrecht 179–210

Smith E, Naidu R, Alston A M (1998) Arsenic in the soil environment: A review. Adv Agronomy 64: 149-195

Stuben D, Berner Z, Chandrasekharam D , Karmakar J (2003) Arsenic enrichment in groundwater of West Bengal, India: geochemical evidence for mobilization of As under reducing conditions. Appl Geochem 18: 1417–1434

Swedish Environmental Protection Agency (EPA) (1999) Bedomningsgrunder for miljokvalitet: Grundvatten. Naturvardsverket rapport 4915, Naturvardsverket forlag, Uppsala

Tsutsumi M (1980) Intensification of arsenic toxicity to paddy rice by hydrogen sulphide and ferrous iron I. Induction of bronzing and iron accumulation in rice by arsenic. Soil Sci Plant Nutr 26:561–569

Turpeinen RR, Panstar-Kallio M, Haggblom M, Kairesalo T (2002) Role of microbes in controlling the speciation of arsenic and production of arsines in contaminated soils. Sci Total Environ 285: 133-145

Turpeinen RR, Panstar-Kallio M, Haggblom M, Kairesalo T (1999) Influence of microbes on the mobilization, toxicity and biomethylation of arsenic in soil. Sci Total Environ 236: 173-180

Uddin MK (1998) Arsenic contamination of irrigated sols, groundwater and its transfer into crops in some areas of Bangladesh. MSc. Thesis. Department of Soil, Water and Environment, University of Dhaka, Dhaka 1000, Bangladesh

UNEP (United Nations Environment Program) (2000) Global Environment Outlook 2000. Earthscan , UK

Wasay SA, Parker W, Van Geel PJ, Barrington S, Tokunaga S (2000) Arsenic pollution of a loam soil: retention form and decontamination. J Soil Contamin 1: 51-64

Wenzel WW, Brandstetter A, Wutte H, Lombi E, Prohaska T, Stingeder G, Adriano DC (2002) Arsenic in field-collected soil solutions and extracts of contaminated soils and its implication to soil standards. J Plant Nutr Soil Sci 165: 221-228

WHO (2001) Arsenic and arsenic compounds, second ed. IPCS Environmental Health Criteria Document 244. International Program on Chemical Safety, WHO, Geneva

Williams PN, Islam MR, Adomokao EE, Raab A, Hossain SA, Zhu YG, Feldman J, Mehrag A A (2006) Increase in rice grain arsenic for regions of Bangladesh irrigating paddies with elevated arsenic in groundwaters. Environ Sci Technol 40: 4903-4908

Xie ZM, Huang CY (1998) Control of arsenic toxicity in rice plants grown on an arsenic-polluted paddy soil. Soil Sci Plant Anal 29:2471–2477

Xiong XZ, Li PJ,Wang YS, Ten H, Wang LP, Song SH (1987) Environmental capacity of arsenic in soil and mathematical model. Huanjing Kexue 8:8-14

CHAPTER 3

(CAPÍTULO 3)

Distribution of Arsenic and Trace Metals in the Floodplain Agricultural Soil of Bangladesh

(Paper publuished electronically in Journal; Bulletin of Environmental Contamination and Toxicology)

Bull Environ Contam Toxicol
DOI 10.1007/s00128-008-9502-x

Distribution of Arsenic and Trace Metals in the Floodplain Agricultural Soil of Bangladesh

Dewan Ali Ahsan · Tomas Angel DelValls · Julian Blasco

Received: 13 November 2007 / Accepted: 14 July 2008

Abstract Arsenic contaminated groundwater of Bangladesh is one of the largest natural calamities of the world. Soil samples were collected from floodplain agricultural land of Faridpur and Dhamrai regions to estimate the concentration of arsenic and other trace metals (copper, nickel, zinc, chromium, cadmium, lead, selenium, cobalt, mercury, and manganese). Average arsenic in Faridpur soil was recorded more than three times higher than the world limit and nearly five times higher than that of Dhamrai. The average copper, chromium and cobalt both in Faridpur and Dhamrai agricultural soil were also higher than the Dutch and the world standards. Both Fardipur and Dhamrai soil contain low amount of selenium in comparison to world limit (0.7 mg kg^{-1}). A poor correlation between manganese and arsenic was noticed in Faridpur. This may be played a subordinate role in the fixation of arsenic in soil. This study also reveals that the area which has arsenic and trace metal contaminated groundwater may also contain high level of arsenic and trace metals in the agricultural soil due to irrigation with contaminated groundwater.

Keywords Bangladesh · Arsenic · Pollution · Agricultural soil

D. A. Ahsan (✉) · T. A. DelValls
UNESCO/UNITWIN/WiCop. Department of Physical-Chemistry. Faculty of Marine and Environmental Sciences, University of Cadiz, Campus Rio San Pedro, 11510 Puerto Real, Cadiz, Spain
e-mail: daahsan@yahoo.com

J. Blasco
Department of Ecology and Coastal Management, Institute of Marine Science of Andalusia (CSIC), Campus Rio San Pedro, 11510 Puerto Real, Cadiz, Spain

Arsenic is a very toxic metalloid. It has a serious impact on the human health. Several million people are at risk from arsenic (As) contaminated drinking water in India (Chatterjee et al. 1995), Bangladesh (Bhattacharya et al. 2002) and China (Wang et al. 2003). The problem of As contamination groundwater of Bangladesh has been considered as dreadful proportion as nearly 75 million people are now at high risk (Chatterjee et al. 1995). The ground water As concentration is recorded from <2.5 to 846 μg L^{-1} in Bangladesh. The survey of Frisbie et al. (2002) revealed unsafe levels of manganese (Mn), lead (Pb), nickel (Ni), and chromium (Cr) in drinking water of Bangladesh. Norra et al. (2005) reported the average concentration of As, zinc (Zn), copper (Cu), lead (Pb), and organic carbon (OC) in rice field (irrigated with As rich groundwater) as 101 mg kg^{-1}, 38.2 mg kg^{-1}, 48.3 mg kg^{-1}, 22.8 mg kg^{-1}, and 1.4%, respectively in West Bengal, India. The concentrations of Cd, Cu, Pb, and Zn were found in the range of 0.01–0.12 mg kg^{-1}, 0.10–2.90 mg kg^{-1}, 0.02–0.23 mg kg^{-1}, and 0.51–3.35 mg kg^{-1}, respectively in soil of Lagos, Nigeria (Awofolu 2005). Soil Cd range was recorded from 0.46 to 1.04 mg kg^{-1} in some parts of China (Dong et al. 2001). Arsenic and trace metal rich ground waters have been using for irrigation in Bangladesh for several decades. So, the top soil of Bangladesh may be at high risk of contamination from arsenic.

The inorganic form of As is toxic to human being. Arsenic and trace metal can inter into the plants from soil and hence in food chain from contaminated soil and may infect human being as well. The terrestrial plants can accumulate a large amount of arsenic (inorganic form) from soils and transfer it to the aboveground biomass (Zhang et al. 2002). On the other hand, marine plants and animals have arsenic detoxification system and for this reason a large amount of arsenic in marine organisms is found in organic forms, such as arsenosugars in algae, and arsenobetaine and arsenocholine in fish, mollusks, and crustaceans (Francesconi et al. 1994). However, terrestrial plants do not have arsenic detoxification system and this is perhaps the reason why inorganic arsenics are predominant in terrestrial plants (Mattusch et al. 2000). A few studies have been conducted to find out the distribution of As and other trace metals in floodplain agricultural soil of Bangladesh. So, the current study has been taken to get an idea about the magnitude of soil contamination with As, Cu, Pb, Mn, Fe, Zn, Co, Se, Hg, Cd, Cr, and Ni in floodplains agricultural soil of two regions [Faridpur (FD) and Dhamrai (DM)] of Bangladesh.

Materials and Methods

The surface soils samples were collected from floodplain agricultural fields of Faridpur (l23°10′ to 23°40′ N and 89°35′ to 90°10′ E) and Dhamrai (23°50′ to 24°05′ N and 90°00′ to 90°20′ E) during dry season (15–29th December, 2006). Ground water has been using for irrigation in dry season in these areas.

Composite soil samples (about 500 g each for different analysis) were collected at a depth of 0–3 cm level. The area of each sampling field was between 0.5 and 5 ha. Samples were transferred into zip locked polythene bags for analysis with proper labeling. Soils samples were dried in room temperature and sieved with a sieve of <2 mm fraction (ISO/DIS 11464). After that, the samples were transferred into zip locked polythene bags. All the samples were then transferred to University of Cadiz, Spain for chemical analyses.

About 0.5 g dried sample was transferred into HP 500 vessel for total digestion. After that 10 mL of deionised water (milliQ water) was added. A mixture of 5 mL of HNO_3, 4 mL of HF, and 1 mL of HCL was also added. The vessels were then inserted into a microwave (CEM MARS 5) and heated at 210°C for 20 min at 175 PSI pressure. After cooling the vessels at room temperature, the caps of the vessels were opened slowly and 30 mL of boric acid solution were added in each vessel. Then the samples were again heated at 210°C for 5 min at 175 PSI pressure. After cooling the digested samples were transferred into a volumetric flask and made up to the final volume (50 mL) with deionised water. The samples were then transferred into plastic containers and kept in refrigerator at about 4°C prior to analysis. All reagents were analytical grade or Suprapur quality (Merck, Germany). Milli-Q water (Millipore, Bedford, MA, USA) was used in all experiments. Cleaning of plastics and glassware was carried out by soaking in 14% (v/v) HNO_3 for 24 h and then rinsing with water.

All digested samples were analyzed for As, Hg, Pb, Co, and Se by ICP-MS and Fe, Mn, Cr, Cu, Zn, and Ni by ICP-AES. Cadmium was determined by GF-AAS. Reactive blanks and reference material (CRM 478 BCR) were used to ensure the quality control. The concentration was calculated on a dry weight basis. The organic carbon concentration was determined by using El Rayis (1985) method.

Statistical analyses were performed on a personal computer using Microsoft Excel programme. A probability level of $p < 0.05$ was considered for statistically significance.

Results and Discussion

The present study showed that in the soil of Faridpur (FD) and Dhamrai (DM) the average As concentration were 33.15 mg kg^{-1} and 6.10 mg kg^{-1}, respectively (Tables 1 and 2). The positive correlations of As with trace metals (Cu, Pb, Mn, Fe, Zn, Co, Se, Hg, Cd, Cr, and Ni) were found both in Faridpur and Dhamrai. The average As concentration in Faridpur was more than three times higher than the world standard (10 mg kg^{-1}) for soil and 100% of the samples exceeded the world's guideline. This value is also much higher than the average As (13.3 mg kg^{-1}) of Samta village one of the As rich areas of Bangladesh (Alam et al. 2003).

The ground-water of Faridpur is highly contaminated with As (Frisbie et al. 2002) and the contaminated water has been using for irrigation for long time. The present study indicated that Faridpur soils contained five times more As than Dhamrai soil. This may be occurred due to use of As rich groundwater for irrigation of rice. The mean concentration of Zn was estimated 97.24 mg kg^{-1} in soil of Faridpur, whereas Zn concentration was recorded 98.85 mg kg^{-1} in soil of Dhamrai (Tables 1 and 2). However, the average Zn was higher than the world standard for Zn (90 mg kg^{-1}) and 87% of the samples exceeded that level. Arsenic and Zn correlation ($r = 0.0136$) was relatively poor in Faridpur soil, whereas that correlation ($r = 0.84$) was significant in Dhamrai (Tables 3 and 4).

This finding indicates that Zn concentration may effect the As fixation in the soil. The mean concentrations of Zn both in Faridpur and Dhamrai soils were lower than the Dutch standard for Zn (140 mg kg^{-1}). This value is also lower than the Zn concentration in soil Nigeria (Awofolu 2005). Zinc is an essential element for human health.

The present study found the average Mn concentrations were 449.68 and 553.75 mg kg^{-1} in the soil of Faridpur and Dhamrai, respectively (Tables 1 and 2). Average Mn is lower than the limit of the world standard in both areas. However, the average Mn of these two areas is higher than the Mn (386 mg kg^{-1}) in paddy soil of China (Wang et al. 2003).

Table 1 Arsenic and trace metals in soil of Faridpur (FD), Bangladesh with comparison to Dutch and World limit

Metals	Present study (range)	Present study (average)	Dutch standard[a]	World limit[a]
(mg kg $^{-1}$ dry soil)				
As	17.59–65.03	33.15	29	10
Cu	38.20–63.55	48.42	36	30
Ni	42.21–61.01	48.85	35	50
Zn	82.69–117.36	97.24	140	90
Cr	73.50–108.14	85.95	100	70
Cd	0.12–0.17	0.153	0.8	0.35
Pb	24.32–33.95	26.82	85	35
Se	0.57–1.37	1.04	0.7	7
Co	14.60–22.09	17.40	9.0	8
Hg	0.05–0.09	0.081	0.3	–
Mn	374.09–575.17	449.68	–	1,000
Fe (mg g $^{-1}$)	40.87–56.27	48.37	–	–

[a] Coskun et al. (2006)

Table 2 Arsenic and trace metals in soil of Dhamrai (DM), Bangladesh with comparison to Dutch and World limit

Metals	Present study (range)	Present study (average)	Dutch standard[a]	World limit[a]
(mg kg $^{-1}$ dry soil)				
As	3.11–8.93	6.10	29	10
Cu	29.61–33.71	31.84	36	30
Ni	43.80–47.94	46.09	35	50
Zn	78.88–125.87	98.85	140	90
Cr	45.60–84.38	76.08	100	70
Cd	0.11–0.22	0.155	0.8	0.35
Pb	23.22–26.61	24.85	85	35
Se	0.623–1.31	1.01	0.7	7
Co	15.41–17.26	16.41	9.0	8
Hg	0.05–0.12	0.78	0.3	–
Mn	471.09–655.24	553.75	–	1,000
Fe (mg g $^{-1}$)	32.70–41.30	37.00	–	–

[a] Coskun et al. (2006)

Manganese correlated significantly with As ($r = 0.86$) in Dhamrai soil, whereas that correlation ($r = 0.0261$) was insignificant in Faridpur soil (Tables 3 and 4). The poor correlation of Mn with As in Faridpur may play a subordinate role in the fixation of As in soil because oxidized Mn phases are well known for their ability to adsorb high amounts of As (Chiu and Hering 2000).Selenium concentrations in Faridpur and Dhamrai soils were 1.04 and 1.01 mg kg^{-1}, respectively (Tables 1 and 2) and 100% of samples of the both the areas were under the world standard of Se (7 mg kg^{-1}). Selenium and arsenic correlations of FD ($r = 0.0420$) were very poor and insignificant in comparison to that of DM ($r = 0.94$) (Tables 3 and 4). The average Se in soil of Faridpur and Dhamrai were also very lesser than the average Se (0.25 mg kg^{-1}) of China (Wang et al. 2003). Selenium is an important element of the human body which prevents the cytotoxic effect of As. The average Se contents (0.003 µg L^{-1}) in Bangladesh groundwater is very low in comparison to WHO limits (0.010 µg L^{-1}) (Frisbie et al. 2002).This general deficiency of Se both in soil and water can decreases the Se level in human body and hence increases the intensity of arsenic related diseases.

The mean concentrations of Fe in soil of Faridpur and Dhamrai were found 48.37 and 37.00 mg g^{-1}, respectively (Tables 1 and 2). A positive insignificant correlation between As and Fe were obtained both in Faridpur ($r = 0.36$) and Dhamrai ($r = 0.39$). Norra et al. (2005)

Table 3 Correlation coefficient matrix for soil parameters of Faridpur (FD), Bangladesh

	As	Cu	Ni	Zn	Se	Co	Hg	Cr	Cd	Pb	Mn	Fe
As	1.00											
Cu	0.3140	1.00										
Ni	0.0003	0.1491	1.00									
Zn	0.0136	0.0841	0.839 (S)	1.00								
Se	0.0420	0.0615	0.3133	0.3313	1.00							
Co	0.0043	0.2001	0.9315 (S)	0.7232 (S)	0.3519	1.00						
Hg	0.1409	0.0893	0.3343	0.4474	0.5379 (S)	0.25	1.00					
Cr	0.0078	0.2152	0.9755 (S)	0.7253 (S)	0.2752	0.95 (S)	0.23	1.00				
Cd	0.0453	0.0085	0.4245	0.4242	0.2123	0.27	0.14	0.36	1.00			
Pb	0.0111	0.1389	0.9514 (S)	0.7521 (S)	0.2407	0.86 (S)	0.23	0.93 (S)	0.40	1.00		
Mn	0.0261	0.0473	0.5766 (S)	0.5111 (S)	0.6682 (S)	0.63 (S)	0.17	0.57 (S)	0.29	0.57 (S)	1.0	
Fe	0.3682	0.0048	0.5364 (S)	0.4830	0.2035	0.59 (S)	0.34	0.49 (S)	0.20	0.43	0.15	1.0

S = Significance at 5% level

Table 4 Correlation coefficient matrix for soil parameters of Dhamrai (DM), Bangladesh

	As	Cu	Ni	Zn	Se	Co	Hg	Cr	Cd	Pb	Mn	Fe
As	1.00											
Cu	0.74	1.00										
Ni	0.79 (S)	0.97 (S)	1.00									
Zn	0.84 (S)	0.81 (S)	0.85 (S)	1.00								
Se	0.94 (S)	0.64	0.74	0.84 (S)	1.00							
Co	0.76	0.79 (S)	0.89 (S)	0.91 (S)	0.84 (S)	1.00						
Hg	0.30	0.21	0.28	0.59	0.46	0.57	1.00					
Cr	0.50	0.39	0.54	0.41	0.66	0.65	0.22	1.00				
Cd	0.67	0.80 (S)	0.78 (S)	0.93 (S)	0.63	0.79 (S)	0.56	0.21	1.00			
Pb	0.81 (S)	0.64	0.70	0.95 (S)	0.86 (S)	0.85 (S)	0.72	0.39	0.86 (S)	1.0		
Mn	0.86 (S)	0.88 (S)	0.91 (S)	0.99 (S)	0.83 (S)	0.91 (S)	0.50	0.42	0.93 (S)	0.91 (S)	1.0	
Fe	0.39	0.81 (S)	0.73	0.67	0.32	0.60	0.26	0.11	0.82 (S)	0.5	0.7	1.0

S = Significance at 5% level

reports that Fe- oxides/hydroxides may play a significant role in fixation of As but the present study does not show this tendency. However, soil texture, crystallinity, pH, conductivity and total alkalinity also play significance role in this regard. The average Ni concentrations were 48.85 and 46.09 mg kg^{-1} in Faridpur and Dhamrai, respectively (Tables 1 and 2). Nickel concentration (both FD and DM) exceeded the Dutch standard (35 mg kg^{-1}) but did not exceed the world limit (50 mg kg^{-1}). The average Ni in Faridpur and Dhamrai were lower than Ni (25.5 mg kg^{-1}) of paddy soil in China (Wang et al. 2003). Relatively strong positive significant correlations of Ni with As ($r = 0.79$) were obtained in Dhamrai, whereas the correlation of Ni and As ($r = 0.0003$) was insignificant in FD (Tables 3 and 4).

Copper concentrations in Faridpur and Dhamrai were 48.42 and 31.84 mg kg^{-1}, respectively which exceeded the world limit for Cu (30 mg kg^{-1}) in soil (Tables 1 and 2). These values are also higher than the average Cu concentration (30 mg kg^{-1}) of Samta Village, Bangladesh (Alam et al. 2003). However, the average Cu of Faridpur agricultural soil is nearly similar to the Cu concentration (48.3 mg kg^{-1}) of rice field soil of neighbouring West Bengal, India (Norra et al. 2005). The correlation coefficient of Cu with As was insignificant ($r = 0.3140$ and 0.74) both in Faridpur and Dhamrai. On the other hand, the average Cd in Faridpur (0.153 mg kg^{-1}) and Dhamrai (0.155 mg kg^{-1}) were nearly same and did not exceed the Dutch standard (0.8 mg kg^{-1}) and world limit (0.35 mg kg^{-1}) as well (Tables 1 and 2). The average Pb (26.82 mg kg^{-1}) and Hg (0.081 mg kg^{-1}) of Faridpur soil did not exceed the limit of Dutch standard for good soil and world limit as well (Table 1). Lead of Dhamrai floodplain soil did not exceed the Dutch standard and world limit but

Hg (0.78 mg kg^{-1}) was found higher than Dutch regulation (Table 2). The average Pb concentration in both Faridpur and Dhamrai did not exceeded the average Pb (28 mg kg^{-1}) of Samta village, Bangladesh (Alam et al. 2003). However, Pb in Faridpur and Dhamrai soil is slightly higher than Pb (22.8 mg kg^{-1}) in agricultural soil (paddy field) of West Bengal, India (Norra et al. 2005).

The present study also reported that Cr (85.95 mg kg^{-1}) concentration in Faridpur soil was higher than the world limit (70 mg kg^{-1}) and 100% samples exceeded that limit (Table 1), whereas Cr level in Dhamrai (76.08 mg kg^{-1}) was lower than Dutch regulation but higher than the world standard. Average Co was nearly same both Faridpur (17.40 mg kg^{-1}) and Dhamrai (16.41 mg kg^{-1}). Copper concentration has been exceeded the world limit in both areas as well (Table 2). The concentrations of soil Cr and Co in DM and FD were also higher than the concentration of Cr and Co in rice field of China (Wang et al. 2003).

So, the most important finding of the present study is that the soil of Faridpur contains nearly four times higher As than the world limit and more than five times higher As than the soil of Dhamrai. This study also predicts that the area which has As contaminated ground water may also contain high level of As in the agricultural soil due to irrigation with ground-water. However, further studies are essential to draw the final conclusion in this regard. More studies are also required to determine the concentration of As and trace metals in agricultural soil of other areas of Bangladesh. It is also important to find-out the mechanisms of arsenic and trace metals uptake, translocation and transformation in rice and vegetable plants.

Acknowledgements This work has been funded by UNESCO/UNITWIN/WiCop under the environmental quality research activities of University of Cádiz.

References

Alam MG, Snow ET, Tanaka A (2003) Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. Sci Total Environ 308:83–96. doi:10.1016/S0048-9697(02)00651-4

Awofolu OR (2005) Survey of trace metals in vegetation, soil and lower animal along some selected major roads in metropolitan city of Lagos. Environ Moni Assess 105:431–447. doi:10.1007/s10661-005-4440-0

Bhattacharya P, Jacks G, Frisbie SH, Smith E, Naidu R, Sarkar B et al (2002) Arsenic in the environment, a global perspective. In: Sarkar B (ed) Heavy metals in the environment. Marcel Dekker Inc, New York, pp 147–215

Chatterjee A, Das D, Mandal B (1995) Arsenic in groundwater of six districts of West Bengal: the biggest arsenic calamity in the world. Part 1. Arsenic species in drinking water and urine of affected people. Analyst 120:640–650. doi:10.1039/an9952000643

Chiu VQ, Hering JG (2000) Arsenic adsorption and oxidation at manganite surfaces. Method for simultaneous determination of adsorbed and dissolved arsenic species. Environ Sci Technol 34:2029–2034. doi:10.1021/es990788p

Coskun M, Steinnes E, Viladimirovna F (2006) Heavy metal pollution of surface soil in the Thrace region, Turkey. Environ Moni Assess 119:545–556. doi:10.1007/s10661-005-9042-3

Dong WQY, Cui Y, Liu X (2001) Instances of soil and crop heavy metal contamination in China. Soil Sedi Contam 10:497–510. doi:10.1080/20015891109392

El Rayis OA (1985) Re-assessment of the titration method for the determination of organic carbon in recent sediments. Rapp Com Int Mer Medit 29:45–47

Francesconi KA, Edmonds JS, Morita M (1994) Determination of arsenic and arsenic species in marine environmental samples. In: Nriagu JO (ed) Arsenic in the environment part I: cycling and characterization. Wiley and Sons, Canada, pp 189–219

Frisbie SH, Ortega R, Maynard DM (2002) The concentrations of arsenic and other toxic elements in Bangladesh's drinking water. Environ Health Perspect 110:1147–1153

Mattusch J, Wennrich R, Schmidt AC (2000) Determination of arsenic species in water, soils and plants. Fr Esenius J Anal Chem 366:200–203. doi:10.1007/s002160050039

Norra S, Berner ZA, Agarwala P (2005) Impact of irrigation with As rich groundwater on soil and crops: a geochemical case study in West Bengal Delta Plain, India. Appl Geochem 20:1890–1906. doi:10.1016/j.apgeochem.2005.04.019

Wang XC, Yan WD, An Z (2003) Status of trace elements in paddy soil and sediment in Taihu lake region. Chemosphere 50:707–10. doi:10.1016/S0045-6535(02)00209-6

Zhang W, Yong CY, Tub C (2002) Arsenic speciation and distribution in an arsenic hyper accumulating plant. Sci Total Environ 300:167–177. doi:10.1016/S0048-9697(02)00165-1

CHAPTER 4

(CAPÍTULO 4)

Arsenic and Metal Sequential Extraction (BCR approach) for Floodplain Agricultural Soil of Bangladesh: Implications for Environmental Risk Assessment

(Paper under review in the Bulletin of Environmental Contamination and Toxicology)

Arsenic and Metal Sequential Extraction (BCR approach) for Floodplain Agricultural Soil of Bangladesh: Implications for Environmental Risk Assessment

Dewan Ali Ahsan[1], Angel DelValls Casillas[1] and Julian Blasco[2]

1. UNESCO/UNITWIN/WiCop. Department of Physical-Chemistry. Faculty of Marine and Environmental Sciences. University of Cadiz, Campus Rio San Pedro, 11510 Porto Real, Cadiz, Spain

2. Department of Ecology and Coastal Management. Institute of Marine Science of Andalusia (CSIC), Campus Rio San Pedro, 11510 Porto Real, Cadiz, Spain

✉ **D A Ahsan**

Email: daahsan@yahoo.com

Abstract Sequential extraction technique (BCR; Bureau Community of Reference) was used to analyze the partitioning of arsenic and other eleven trace metals (copper, nickel, zinc, chromium, cadmium, lead, selenium, cobalt, mercury, iron and manganese) in floodplain agricultural soils from Dhamrai and Faridpur regions of Bangladesh. The result of this study indicates that cadmium is highly mobile trace metals in both the Dhamrai and Faridpur regions. The Faridpur soil contains high level of arsenic in comparison to the world standard. Thought the high level of arsenic is recorded in Fardipur soil but arsenic is mostly found with residual fraction in both areas which indicates that arsenic is non-mobile fraction in soil. Geo-accumulation index, Environmental Risk Factor and Metal Pollution index calculated for this study suggest that the soil of Dhamrai and Faridpur are non contaminated from arsenic and other trace metals and there is no risk situated with analyzed metals.

Keywords Arsenic . Soil pollution . BCR . Trace metals

Bangladesh is a country of 150 million people which economy is basically depended on agriculture. Rice is the staple food of Bangladeshi people and the country is still not self-sufficient to produce its own food grain. The farmers of Bangladesh have been using ground water (in dry season) for irrigation of paddy fields for many years. The ground water of Bangladesh is highly polluted with arsenic (Bhattacharya et al.2002) and As rich groundwater is not only using for drinking purpose but also for the irrigation of paddy fields.The agricultural soil of Bangladesh is in deficit of N, P and Zn. As a result chemical fertilizers (especially NPK) have been applying for the increased rice production. The use of As rich ground water for irrigation and unbalance use of chemical fertilizers could be the potential threats to the ecosystem (Eriksson 1990 ; Lorenz et al. 1994 ; Kuo and McNeal

1984). In this sense, it is very important to know the status and mobility pattern of arsenic and other trace metals in agricultural soil of Bangladesh as the distribution and mobility patterns of metals give the clear insight into the contamination status of an ecosystem. Chemical speciation is the most common technique to understand the behavior of metals in natural system (Saenz et al. 2003). It allows one to determine the availability and mobility of the metals in order to understand their chemical behavior and fate.

Tessier sequential extraction procedure is one of the best-known sequential extraction schemes (Tessier et al. 1979). This procedure consists of five steps in which metals are extracted among different phases. So far, many single or sequential extraction procedures (mainly based on the Tessier procedure or its different versions) have been applied to soils and sediments to fractionate metals by using different extractants or reagents to obtain more useful information about the bioavailability and mobility of metals. In this case, the fraction of a metal depends on the extractants and the operating conditions in which the extraction is carried out. A new methodology is introduced by the European Union which is known as the Bureau Community of Reference (BCR) procedure to harmonize the previous methodologies (Rauret et al. 1999). This procedure consists of three sequential extraction steps to fractionate of trace metals in soil and sediment samples .The BCR sequential extraction procedure has been widely applied to analyze the trace metals in soil and sediment samples (terrestrial or marine sources) by a number of investigators (Fernandez et al. 2004). In the present study, the BCR sequential extraction procedure has been performed for the determination of arsenic and other eleven trace metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Fe, Hg and Zn) in soils collected from Dhamrai (DM) and Faridpur (FD) areas of Bangladesh to evaluate the mobility and the risk assessment for arsenic and other trace metals.

Materials and Methods

The surface soils samples were collected from floodplain agricultural fields of Faridpur (FD) (l23^{0}10$^{/}$ to 23^{0}40$^{/}$ N and 89^{0}35$^{/}$ to 90^{0}10$^{/}$ E) and Dhamrai (DM) (23^{0}50$^{/}$ to 24^{0}05$^{/}$ N and 90^{0}00$^{/}$ to 90^{0}20$^{/}$ E) of Bangladesh during dry season .

Composite soil samples (about 500 g each for different analysis) were collected at a depth of 0-3cm level. In total fourteen [eight stations from FD (F1-F8) and six stations from DM (D1-D6)] sampling stations were selected to collect the soil samples. The area of each sampling field is between 0.5-5 ha. Samples were transferred into zip locked polythene bags for analysis with proper labeling. Soils samples were dried in room temperature and sieved with a sieve of < 2 mm fraction (ISO/DIS 11464). After that the samples were stored into zip locked polythene bags for chemical analysis. BCR sequential extraction procedure was followed to extract the trace metals as mentioned earlier. The BCR sequential extraction procedure is briefly shown in Table 1.All extracted samples were analyzed for As, Hg, Pb, Co and Se by ICP-MS and Fe, Mn, Cr, Cu, Zn and Ni by ICP-AES. Cadmium was determined by GF-AAS. The concentration was calculated on a dry weight basis. All reagents used were analytical grade or Suprapur quality (Merck). Standard working solutions of different elements analyzed were prepared from the corresponding 1,000mg⁄L of Merck Titrisol solutions.Comparison between sampling stations were performed by cluster analysis using the Statistica software. The algorithm used was the normalized Euclidian distance between the centered clusters.

Results and Discussion

The total concentration of trace metals (DM and FD soil) extracted in four fractions (F1, F2, F3 and Residual fraction) of BCR sequential extraction are showed in Figure 1 and 2. The contents (%) for each trace metals for each extraction step and residual fraction are illustrated in Figure 3 and 4.

Cadmium seems (both in DM and FD) to be easily mobilized in the fraction 1 while Fe, Pb, Se, Hg Cr and Cr are the very minimum mobilisable elements in this stage. The order of mobility of the metals in the first fraction is Cd > Mn > Zn > Cu > Co>Ni > As in DM soil while the order of mobility of the metals is slightly different (Cd > Mn > Co > Cu > Zn>Ni > As) in soil of FD. Furthermore, the mobility orders of the elements for the second fraction is Pb > Cu > Cd > Zn > Mn > Fe> Co > Se > Cr > Ni > As in soil samples of DM. On the other hand the mobility orders of the metals of soil of Faridpur is Pb > Cu > Cd > Mn > Zn > Co> Fe > Hg > Se > As > Ni > Cr which is slightly differ from that of Dhamrai. Pb, Fe, Se, Hg and Cr are seemed to be mobile in second fraction, whereas Pb is much more mobile in this fraction than all other elements. The order of metals mobilization in third fraction (Se>Co= Ni>Cr>Zn>Cu=Mn>As>Pb>Fe) is nearly similar both in DM and FD soil samples.

The present study shows that Cd is the most mobile elements and 100% of its total concentration is measured in the first and second extraction stages. Cadmium mainly bounds with carbonates and for this reason it is the most mobilized metals in soil (Tokalioglu et al. 2003). Moreover, the increased concentration of Cd in F2 could be the result of indiscriminate use of urea fertilizer in paddy field (Tu et al. 2000). The high amount of Cd associated with the non-residual phases indicates that it may be easily transferred into the food chain through water reservoirs, uptake by plants growing in the soils or by any other mechanism. The high content (~60%) of Cd associated with the acid soluble sample phase shows that its availability is susceptible to pH or ionic composition changes in the environment. Chlopecka et al. (1996) also reported the similar result. The relative high proportion of mobile Cd (F1+F2) in the surface soil indicates that surface soil contamination with Cd originating from anthropogenic activities increased the mobile form of Cd. These observations are in agreement with those of Kashem et al. (2007) and Chlopecka et al. (1996), both of whom report that metals from anthropogenic sources are more mobile than those derived from parent materials. The study of Udom et al. (2004) reveals a higher proportion of mobile Cd in the surface horizons may represent potential health and phytotoxic problems. On the other hand, no detectable amount of Cd is extracted in fraction 3 and residual fraction as well. This result is in consistent with Baron et al. (1990) who found very small amount of Cd in the organic matter faction. This result indicates that Cd in the organic fraction is consistent with the low ion adsorption constant of Cd to organic matter (Chlopecka et al.1996).Keefer et al. (1984) reported that Cd dose not appear to form a strong complex with OC (organic carbon).

Table 1 The BCR steps of BCR sequential extraction scheme

Extraction steps	Reactive / concentration / pH	Solid phases
1 (F1)	Acetic acid: CH_3COOH (0.11 mol L^{-1}), pH 2.85	Exchangeable, water and acid soluble (e.g., carbonates)
2 (F2)	Hydroxylammonium chloride: $NH_2OH{\cdot}HCl$ (0.1 mol L^{-1}) at pH 2	Reducible (e.g., iron/manganese oxides)
3 (F3)	Hydrogen peroxide: H_2O_2 (8.8 mol L^{-1}), followed by ammonium acetate: CH_3COONH_4 (1.0 mol L^{-1}) at pH 2	Oxidisable (e.g., organic substance and sulphides)
Residual fraction	Total digestion (Aqua regia: 3HCl + HNO_3)	Remaining

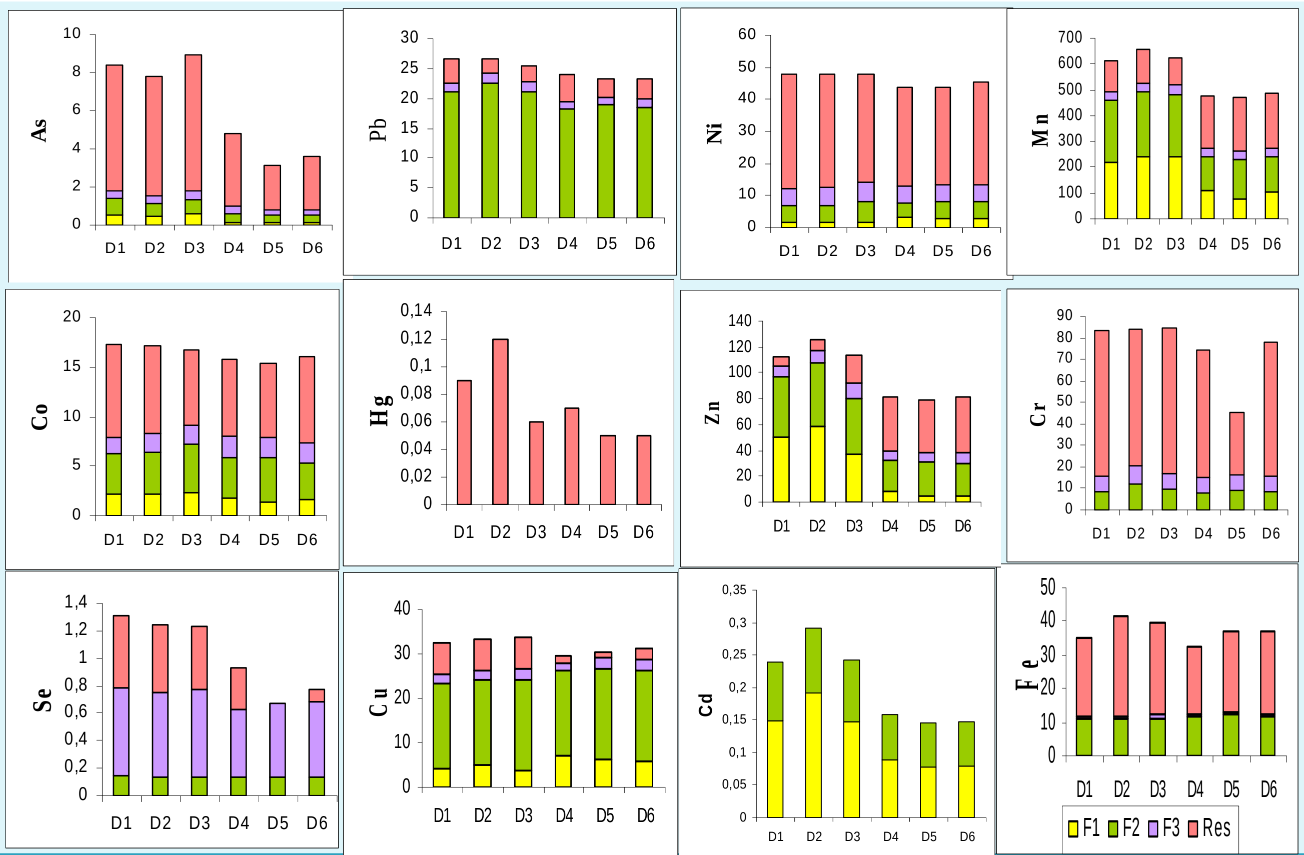


Fig.1: Speciation of trace metals in the agricultural soil of Dhamrai (D1-D6). Results are expressed as µg/g dry wet except for Fe (mg/g dry wt).

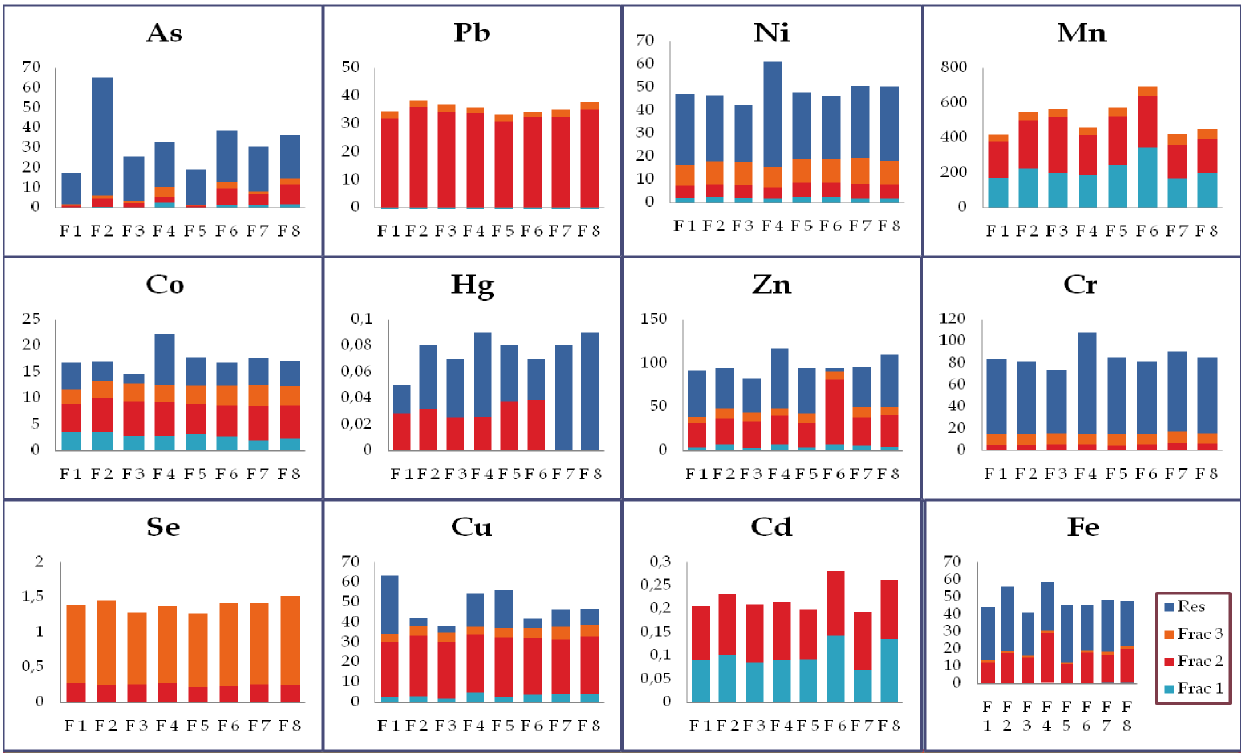


Fig.2: Speciation of trace metals in soil of **Faridpur** (F1-F8). Results are expressed as **µg/g** dry wet except for Fe (mg/g) dry wt.

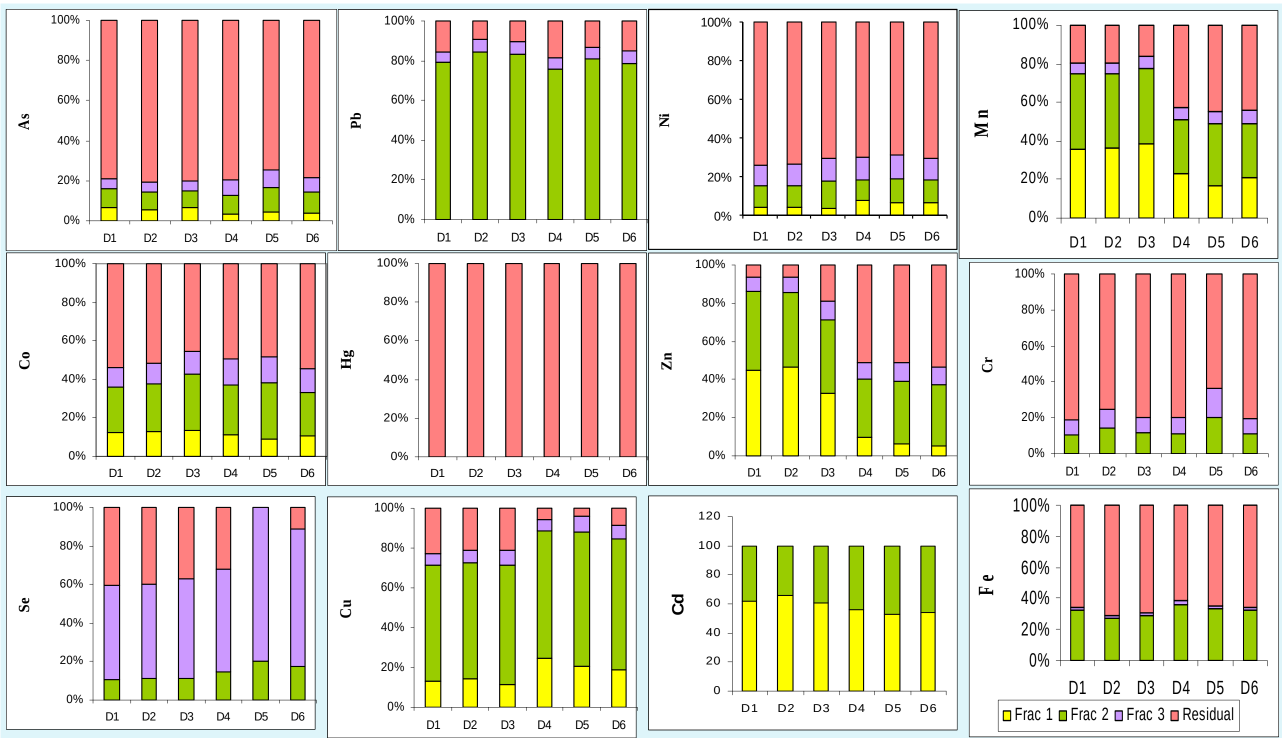


Fig. 3: Speciation of trace metals in the agricultural soil of Dhamrai (D1-D6). Results are expressed as percentage (%) with respect to total digestion

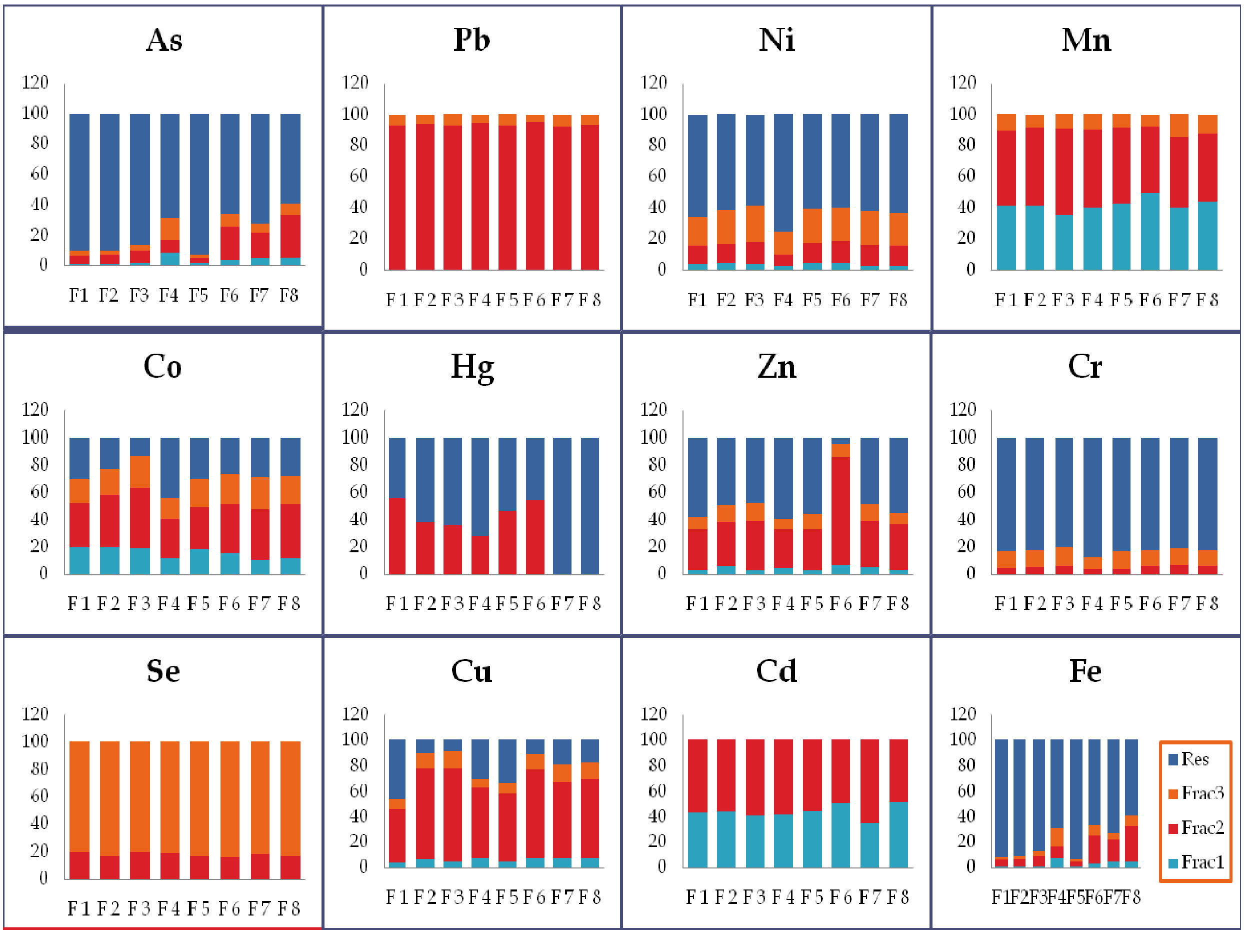


Fig.4: Speciation of trace metals in soil of **Faridpur** (F1-F8). Results are expressed as a percentage (%) with respect to total digestion

Zinc is mainly extracted (~35%) in F2 in both FD and DM soil possibly because of high stability constant of Zn oxides. Several studies have also found Zn to be associated with Fe-Mn oxides (Ma and Rao 1997; Ramos et al.1994; Kashem et al.2007). A significant amount of Zn (47% in FD and 37% in DM) is also found in residual fraction. Ma and Rao (1997) also found Zn to be strongly bound in the residual fraction (even up to 98% of its total content). The present study finds the concentration of Zn in the organically bound fraction is in the range of 8-10% which is also similar to the study of Kashem et al. (2007). The average Zn is lower than the Dutch standard for Zn (140 mg kg^{-1}).Bangladesh soil is basically with Zn deficit. Moreover, Zn content in paddy soil could be declined due to crop harvest (Wang et al. 2003).

Copper (65%) is bound in the Fraction 2 both in FD and DM soil. Rest of the Cu is found nearly in equal concentration in F1, F3 and residual fractions. Wong et al. (2002) reports that in general low amount of (<10%) Cu binds with exchangeable and carbonate-bound phases. The chemical partitioning of Fe in the agricultural soil of FD and DM shows that Fe in the soil is mainly associated in the residual fraction (~60%). The association of

Fe with the Fe–Mn oxide fraction (~30%) is also significant. The agricultural soils of FD and DM under go successive tillage (at least two times a year) for increase food production. Shuman and Hargrove (1985) find that Fe concentration is higher in residual and F3 fractions in tillage soil than the non tillage soil.

Manganese in soil of the both DM and FD regions is nearly equally extracted in F1 and F2 (~35%). This finding is opposite to the study of Wong et al. (2002) where they finds Mn is predominantly associated with the residual fraction. Tillage increase the concentration of Mn in exchangeable and Fe- Mn oxide fractions (Shuman and Hargrove 1985) and perhaps for this reason Mn is also found in higher concentration in F1 and F2 fractions in agricultural soils of Bangladesh.

A significant level of Co is recorded in residual fraction (28 -50%) in both areas. The rest of this metal is associated with reducible (25-35%) and oxidisable fractions (15-20%). Cobalt is probably present as CoS in the oxidisable fraction. Wong et al. (2002) reported the similar results for crop and natural soil in Southern China. The average percentage of mobile Ni is (F1+F2) is nearly 20% in both DM and FD soil samples. This observation suggests that Ni is less mobile in soil which is also supported by the findings of Kashem et al. (2007).

Arsenic in soil of DM and FD is mainly found in the residual fraction (~75%). On the other hand a significant concentration of Se (60-80%) is bound in the F3 fraction. The strong association between soil Se and the organic matters is in agreement with the general findings that Se forms the most stable complexes with organic matter which in turn could reduce Se mobility and phytotoxicity in these soils. Hg (~70%), and Cr (~75%) can be considered immobile because of elevated percentage of these metals are found in the residual fraction. These findings are in agreement with the study of Tokalioglu et al. (2003). These metals are strongly bound to minerals; as a result they are non-mobile components of soil.

A cluster analysis is carried out to classify the sampling stations according to their trace metals content and speciation. The dendogram (Figure 5) allows two groups to be established. Group 1 corresponds to all stations (D1- D6) of Dhamrai (DM). All of these sampling sites show the lowest value of trace metals. On the other hand group 2 includes all the sampling stations (F1 to F8) except F4 of Faridpur (FD).

The degree of environmental risk can de predicted by calculating the environmental risk factor (ERF). Environmental risk factor gives the indication whether the soil is polluted with certain metal. ERF for different trace metals was calculated by following formula proposed by Saenz et al. (2003).

$ERF = (C_{SQV} - Ci)/C_{SQV}$; Where;

C_{SQV} = Concentration soil quality value;

Ci = Sum of the trace metal concentrations correspondence to the first three fractions (F1+F2+F3) of BCR

In the present study we considered Ci as the sum of first three fractions of BCR as the metals in these fractions can be mobilized. There is no site specific data for trace metal are available for the soil of DM and FD and other parts of Bangladesh. So, the values for trace metals presented by Urzelai et al. (2000) had been considered as C_{SQV} value for the calculation in present study. For Se, a value of 0.7mg/kg, obtained from Dutch Standard (Swartjes 1999) was considered as C_{SQV}. All sampling sites of DM and FD showed the ERF values were graeter than zero for all metals except Cu. Copper values showed negative

(<-0.6) in all sampling sites both for Dhamrai and Faridpur regions. The source of copper contamination is non anthropogenic as there is no heavy industries in these area.

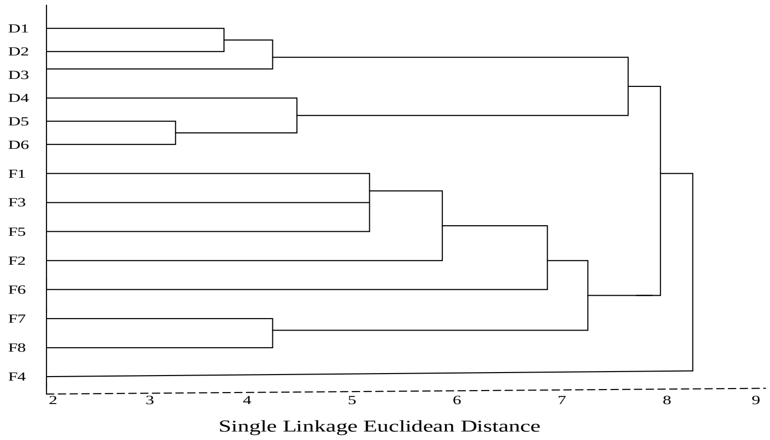


Fig. 5 Dendogram showing clustering of sampling sites (D1-D6) in Dhamrai and (F1-F8) in Faridpur

The geo-accumulation index (Igeo*)* calculation of soil also gives the information about the contamination status of soil. Igeo introduced by Muller (1979) has also been used to assess metal pollution in soil of DM and FD. Geo-accumulation index is expressed as follows;

Igeo = $\log_2$ (Cn/1.5*Bn), Where;
Cn = Total concentration metal is soil sample
Bn = Background value of metal in soil
1.5 is the background matrix correction in factor due to lithogenic effects

The Igeo index showed that all the trace metals of FD and DM soil samples were in Class 0 and Class 1. According to the *I*geo index, the soil if not contaminated with trace metals if the value is < l. The background level of Dutch soil standard (Swartjes 1999) had been employed to calculate the *I*geo index. So, according to the Igeo values, the soil of DM and FD are not contaminated by metals. Karbassi et al. (2006) also reported that *I*geo values could be used effectively and more significantly in explaining the trace metals status in soil.

Metal pollution index (MPI) (Gonçalves et al. 1992) has also been employed to ascertain the contamination status. MPI can be determined by the following formula;

$$MPI = \sum_i \frac{Wi}{Wt} * FC_i$$, where;

FC is the factor which has been previously defined
Wi is a charge coefficient foe each metal
Wt is the sum of the charge coefficient for considered metals
For Wi , the data of Urzelai et al.(2000), has been employed corresponding to the toxoicity values for soil.

If MPI is less than 1, the soil is not contaminated, when MPI is higher than 1, the the soil is contaminated. The result could also be calculated for each zone as well by the following equation;

$$MPI_{area} = [(MPI)_1 * (MPI)_2 * .... * (MPI)_m]^{1/m}$$

The *MPI index* also showed the non-contaminated status for all sampling sites of Dhamrai and Faridpur and these zones as well.

In summary, Environmental Risk Factor (ERF), Geo-accumulation index (Igeo) , and Metal Pollution Index (MPI) show that the agricultural soil of DM and FD is free from arsenic and other trace metals contamination. However, according to ERF Dhmarai and Faridpur soil are contaminated by the trace metal Cu. The present study indicates that FD soil contains three times (average 33.15 mg/kg) more As than the world limit (10 mg/Kg) but As is found mostly in residual fraction in both Dhamrai and Faridpur which indicates that arsenic is immobile and soil arsenic is not available for plants.

References

Baron J, Legret M, Astruc M (1990) Study of interactions between heavy metals and sewage sludge. Determination of stability constant and complexation capacities of complexes formed with Cu and Cd. Environ Technology 11:151–162

Bhattacharya P, Jacks G, Frisbie S H, Smith E, Naidu R, Sarkar B (2002) Arsenic in the environment: a global perspective. In: Sarkar B (ed) Heavy metals in the environment. New York. Marcel Dekker Incorporation, pp 147-215

Chlopecka A, Bacon JR, Wilson MJ, Kay J (1996) Forms of cadmium, lead and zinc in contaminated soils from southwest Poland. Jour Environ Quality 25: 69–79

Eriksson JE (1990) Effect of nitrogen-containing fertilizer on solubility and plant uptake of cadmium. Wat Air Soil Poll 49: 355–368

Fernandez E, Jimenez R, Lallena AM, Aguilar J (2004) Evaluation of the BCR sequential extraction procedure applied for two unpolluted Spanish soils. Environ Pollution 131 :355-364

Goncalves EPR, Boaventura RAR , Moyvet C (1992) Sediments and aquatic mosses as pollution indicator for heavy metals in the Ave River basin. Sci Total Environ 114: 7-24

Fernandez E, Jimenez R, Lallena AM, Aguilar J (2004) Evaluation of the BCR sequential extraction procedure applied for two unpolluted Spanish soils. Environ Pollution 131: 355 364

Karbassi A R, Bayati I , Moattar F(2006) Origin and chemical partitioning of heavy metals in riverbed sediments. Inern. Journal Environ Sci Technol 3: 35-42

Kashem MA, Singh BA ,Kawai S (2007) Mobility and distribution of cadmium, nickel and zinc in contaminated soil profiles from Bangladesh. Nutrient Cycl Agroeco 77:187-198

Keefer RF, Codling EE, Singh RN (1984) Fractionation of metal organic complexes extracted from a sewage sludge-amended soil. Soil Sci Socie Ame Jour 48: 1054–1059

Kuo S , McNeal BL (1984) Effects of pH and phosphate on cadmium sorption by a hydrous ferric oxide. Soil Sci Socie Amer Jour 48: 1040–1044

Lorenz SE, Hamon RE, McGrath SP, Holm PE , Christensen TH (1994) Applications of fertilizer cations affect cadmium and zinc concentrations in soil solutions and uptake by plants. Europ Jour Soil Sci 45 **:**159–165

Ma LQ , Rao GN(1997) Chemical fractionation of cadmium, copper, nickel and zinc in contaminated soil. Jour Environ Quality 26: 259-264

Muller G (1979) Schwermetalle in den sediments des Rheins-Veranderungen seitt 1971. Umschan 79: 778- 783

Ramos L, Hernandez LM , Gonzalez MJ(1994) Sequential fractionation of copper, lead, cadmimum and zinc in soils from or near Donana National Park. Jour Environ Quality 23: 50 -57

Rauret G, Lopez-Sanchez JF, Sahuquillo A, Rubio R, Davidson C, Ure A, Quevauviller PH (1999) Improvement of the BCR three step sequential extraction procedure prior to the certification of new sediment and soil reference materials. Jour Environ Monitoring 1 : 57-61

Sanez V, Blasco J , Gomez-Parra A (2003) Speciation of heavy metals in recent sediments of three coastal ecosystems in the gulf of Cadiz, South-West Iberian Peninsula. Environ Chemistry 22: 2833-2839

Shuman LM (1985) Fractionation method for soil micronutrients. Soil Sci 140: 11-22

Shuman LM , Hargrove WL (1985) Effect of tillage on the distribution of manganese, copper, iron, and zinc in soil fractions. Soil Sci Soci Amer Jour 49: 1117-1121

Swartjes FA (1999) Risk-based assessment of soil and groundwater quality in the Netherlands: standards and remediation urgency. Risk Analy19:1235-1249

Tessier A ,Campbell PGC, Bisson, M(1979) Sequential extraction for the speciation of particulate trace metals. Analy Chemistry 51: 844-851

Tokalioglu S, Kartal S, Birol G (2003) Application of a three-stage sequential extraction procedure for the determination of extractable metal contents in highways soils. Turkish Jour Che 27 : 333 – 346

Toimson DL, Wiolson JG, Harris CR , Jeffrey DW (1980) Problems in the assessment of heavy metals levels in estuaries and the formation of a pollution index. Helgolander Meeresunters 33 : 566-575

Tu C, Zheng CR , Chen HM (2000) Effect of applying chemical fertilizers on forms of lead and cadmium in red soil. Chemosphere 41 : 133-138

Udom BE, Mbagwu JSC, Adesodun JK , Agbim NN (2004) Distribution of zinc, copper, cadmium and lead in a tropical Ultisol after long-term disposal of sewage sludge. Environ International 30: 467–470

Urzelai A, Vega M , Angulo E(2000) Deriving ecological risk-based soil quality values in the Basque Country. Sci Total Environ 247: 279-284

Wang XC, Yan WD, An Z (2003) Status of trace elements in paddy soil and sediment in Taihu lake region. Chemosphere 50: 707-10

Wong SC, Lia XD, Zhang G, Qib SH, MinYS (2002) Heavy metals in agricultural soils of the Pearl River Delta, South China. Environ Pollution 119 : 33–44

CHAPTER 5

(CAPÍTULO 5)

The relationship of national and international environmental NGOs in Bangladesh and their role in wetland conservation and pollution control

(This study partially presented in MSc progarme at University of Plymouth)

(Paper in under review in International Journal Environmental Research)

The relationship of national and international environmental NGOs in Bangladesh and their role in wetland conservation and pollution control

Ahsan , D. A.[1], DelValls, T.A. [1], Blasco, J. [2]

[1] UNESCO/UNITWIN/WiCop. Department of Physical-Chemistry. Faculty of Marine and Environmental Sciences. University of Cadiz, Campus Rio San Pedro, 11510 Porto Real, Cadiz, Spain

[2] Department of Ecology and Coastal Management. Institute of Marine Science of Andalusia (CSIC), Campus Rio San Pedro, 11510 Porto Real, Cadiz, Spain

ABSTRACT: Biodiversity degradation, lose of wetlands and arsenic pollution are becoming the major environmental threats of Bangladesh. Huge number of population, corruption and lack of capacity of the governmental agencies are deteriorating the over environmental condition of Bangladesh. This paper reports the findings of NGOs and their role in protection of wetlands of Bangladesh. Ministry of Environment and Forestry (MoEF) and its daughter organization Department of Environment (DoE) are comparatively weak in power and capacity in comparison to other ministries. To fill up this gap, a number of environmental NGOs (ENGOs) have emerged in Bangladesh after the Rio Earth Summit in 1992. ENGOs are actively involved in the environmental sectors of Bangladesh by doing research, advocacy, companying activities and as pressure group as well. ENGOs are implementing several projects with government and international donor agencies. Their role to protect and manage wetland ecosystem and biodiversity is very praise-worthy. Bangladeshi ENGOs have very good relations with international ENGOs and donor agencies. Most of the Bangladeshi ENGOs (research based) are dependent on the foreign aids. But the prominent companying ENGOs are not interested to seek governmental and international donors' supports to uphold their independence and to raise their voice against environmental damages taking by governmental and private projects.

Key words: ENGOs; Wetland protection; Environmental policy; Bangladesh

---

Corresponding author: Email: daahsan@yahoo.com

INRODUCTION

Serious environmental degradation has taken place in Bangladesh in recent years. It is apprehended that at the end of the 21st century Bangladesh will face serious environmental degradation (Alam, 1988). There are many dimensions of this degradation. Urban air pollution, ground water contamination with arsenic, surface water pollution, encroachment of rivers and other water bodies, improper disposal of industrial, medical, and household waste, deforestation, loss of open space, loss of bio-diversity, and noise pollution are just a few examples. In many cases, the extent of degradation has reached crisis proportions (Islam, 2002).

NGO (Non Governmental Organization) is a very widely known term all over the world. It is very difficult to define NGO but in the broadest sense NGOs mean non governmental, non profitable organizations which main vision is to serve the poor and disadvanced groups of the society. NGOs are involved with micro-credit, environment, family planning, education, heath and sanitation, human right and many other sectors of the society. The donor agencies like the World Bank, UNDP, DFID, CIDA, USAID etc. are encouraging collaboration with international and national NGOs especially in developing worlds.

The environmental NGOs which are also termed as ENGOs are working with the governments and developing agencies to protect the environmental pollutions and biodiversity in many countries of the world (Fig. 1). The 1972 United Nations Conference on the Human Environment in Stockholm represented the landmark in international environment policy. The Period from 1975 to 1980 has been labelled the “social movement” phase in the rise of environmentalism, since it was marked by the increasing politicization of the environmental NGOs (Jamison, 1996).

After the Rio Earth Summit, 1992, the environment NGOs got rapid momentum all over the world. The Rio Earth summit was attended by over 22,000 NGO representatives from 9000 NGOs all over the world (Princen and Finger, 1994). By this time the main achievement of the environmental movement is to create a positive situation and as a result governments are expected to pay much attention to environmental protection issues (Carter, 2001).

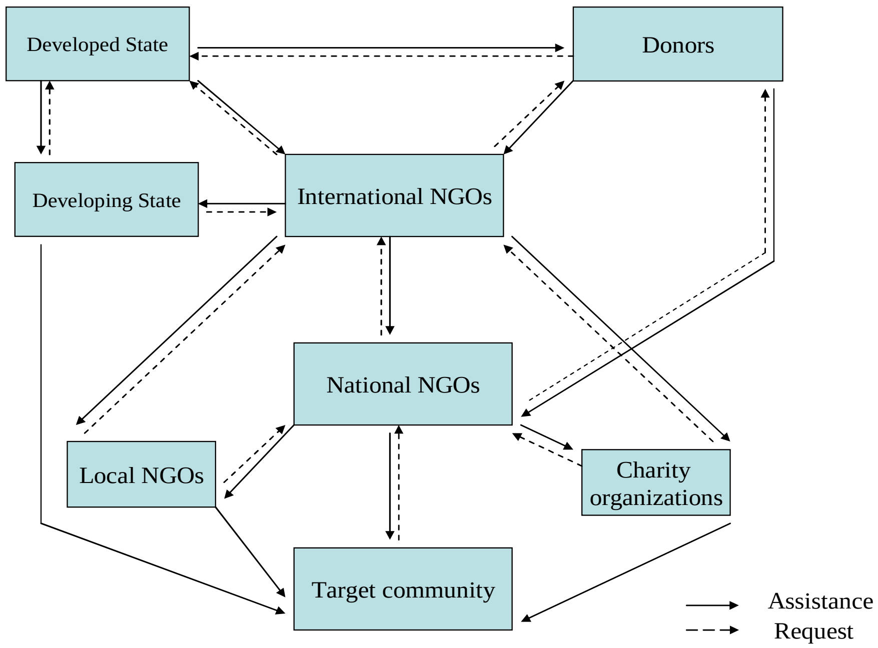


Fig. 1. Relationship among Donor agencies, GOs, NGOs, charity organizations and target community

There are probably more and bigger NGOs in Bangladesh than in any other country of a similar population in the world (Ahmed, 2003). NGO activity in Bangladesh began in the aftermath of the devastating cyclone of the late-1970s and against the backdrop of the war for independence culminating in 1971 (Lewis, 1992). Failure of the national government to successfully operate and manage relief and rehabilitation programs both after independence and following the 1974 flood led the external donors to conclude that the state was inefficient, probably corrupt, and incapable of implementing effective programs. This compelled the donor community including foreign NGOs to look for alternative means of channelling development aid and disaster assistance (Lewis 1992).

After the Rio Earth Summit in 1992, a number of ENGOS and environmental advocacy groups emerged in Bangladesh. By this time, ENGOs (both specialized and not specialized in environment) have formed a coalition, namely Coalition of Environmental NGOs (CEN). Many of these NGOs have collaborated with the Government in formulating NEMAP (National environmental management action plan). Some of these are now engaged in implementation of NEMAP related and other environmental projects, such as SEMP. However, it is clear that these efforts and projects are not proving adequate for the environmental challenges which are facing Bangladesh. The environment in Bangladesh is still deteriorating despite the projects (Islam, 2002).

In Bangladesh understanding of the environment has developed in last few decades. In fact the awareness builds up and conservation effort started in 1980’s when several developments took place (Islam, 2002).During that period a separate Ministry called Ministry of Environment and Forest (MoEF) and The Department of Environment (DoE) have been established. The Department of Environment (DoE) the daughter organisation of MoEF is responsible for the implementation of the adopted policies (Mahjabeen, 2002). Several Environmental acts have been passed (Table 1). Government also formed environmental courts at Dhaka and Chittagong.

Table 1. Key environmental legislations in Bangladesh (modification of Huq, 2002)

Year	Legislation	Primary objectives
1970	Water pollution control ordinance	An ordinance to provide for the control, preservation and abatement of pollution of waters of Bangladesh
1977	The environment pollution control ordinance	An ordinance to provide for control. prevention and abatement of pollution of the environment of Bangladesh
1995	The Bangladesh environment conservation act	An act to provide for conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution
1997	The environmental conservation rules	To exercise the powers conferred by section 20 of the Bangladesh Environmental Conservation Act, 1995, the Government of Bangladesh passed this rule
2000	The environment court act	An act to provide for the establishment of environment courts and matters incidental thereto

A large number of case studies and assessments on NGOs of Bangladesh have been conducted in Bangladesh (Fruttero and Gauri, 2005). But the role of ENGOs on wetland management and their relationships to the government and to donors and international ENGOs have not been addressed.

So, the aims of the present study are to explore the role of environmental NGOs to protect the wetlands of Bangladesh their relation with governmental agencies, donor agencies and international ENGOs.

METHODS

The study was designed to gather information from ENGOs personnel and representatives of regulating agencies as well. The International ENGOs, national ENGOs and governmental agencies were selected on the basis of their involvements environmental and conservation issues. Semi-structured interview technique was selected to collect the data. A questionnaire was formulated to conduct the interviews and collect the data. Probes were also used to develop the deeper understanding of the relevant issues.

A total of 13 semi-structured interviews were conducted (Table 2). Prior to the interview the participants were provided with a brief outline of the project aims and a copy of the questions. These help them to understand the theme of the study. All The interviews were taken in the office premises of the interviewees. The duration of each interview was 20-30 minutes on an average. The discussions were tape recorded with the permission of the respondents and after that transferred those into transcript forms. The data which were obtained from the interviews were processed using framework analysis as mentioned by Ritchie and Spencer (1994). This analysis involved systematically coding, grouping and summarising descriptions and providing a coherent organising thematic framework to explain (Holstein and Gubrium, 1995; Holloway, 1997; Strauss, 1987).

Table 2. Details of interview respondents and their role within the organization

Organizations	Main activities	Interviewees
Greenpeace, UK	Environmental campaigner	Campaigner
IIED *(International Institute for Environment and Development)*,UK	Policy research and facilitator	Director
ACOPS (*Advisory Committee on Protection of the Sea)*,UK	Policy research, advisory, public awareness	Director
IUCN *(The World Conservation Union)*	Conservator	Country Representative
BAPA *(Bangladesh Poribesh Andolan)*	Campaigner	Vice- president
CNRS *(Centre for Natural Resources Studies)*	Research and conservator	Executive Director
BCAS *(Bangladesh Centre for Advanced studies)*	Research and conservator	President
FEJB *(Forum of Environmental Journalists of Bangladesh)*	Campaigner	Chairman
Winrock International	Research and conservator	Country representative
Action Aid , Bangladesh	Advisory, public awareness	Programme Officer
Ongikar Bangladesh Foundation	Campaigner, advisory	Chief director
Sundar Jibon, Bangladesh	Campaigner	President
DoE *(Department of Environment)*,Bangladesh	Regulator	Assistant Director

RESULT & DISCUSSION

Categories of ENGOs in Bangladesh

The present study found several types of ENGOs are working in environmental sector of Bangladesh and which may be categorized as follows (Table 3).

Several international ENGOs (Group 1) are working in Bangladesh with collaboration of the governmental agencies and national and local ENGOs. The research based ENGOs (Group 2) are thinking that the government is doing nothing in environmental conservation. So, they formulate the project proposals and they work in those areas. They are also jointly implementing the governmental projects. BCAS and CNRS are the good examples of those types of ENGOs. On the other hand the pressure groups (Group 3) are trying to put pressure on the government because they find that in some sectors (like wetland conservation , pollution control and biodiversity protection) the government is doing nothing . More over the government is deteriorating the conditions. So they are trying to create pressure on the government to solve the problem. They are also trying to motivate the people. Some cases the government is accepting there ideas. BAPA, BELA (Bangladesh Environmental Lawyers Association), Ongikar Bangladesh are the examples of such types of NGOs.

Table 3. Category of interview NGOs respondents

Organizations		
Gr I	**Gr II**	**Gr III**
International Environmental NGOs	Bangladeshi Environmental NGOs (research based)	Bangladeshi Environmental NGOs (campaigners)
Greenpeace		
IIED		
ACOPS		
IUCN		
Actionaid		
Winrock International		
		BAPA
		FEJB
	BCAS	
	CNRS	
		Ongikar Bangladesh Foundation
		Sundar Jibon

Besides these some interviewees also identified some other ENGOs they are only operating for money either from the donors or from the government. They do not have their own objectives. They want to work on every issue like wetland conservations, child education, women empowerment and others depending on the availability of grants (Haque, 2004). So they are only for money making.

This observation supports the findings of Ebdon (1995) which mentioned that some small NGOs select those activities which could be easily funded by the donors and the government.

Relation of Bangladeshi ENGOs with foreign ENGOs

The partnership and collaboration have been expanded among different stakeholders including international financial institutions, foreign corporations, government agencies, consulting firms, academic and research institutions, local governments, pressure groups, and non-government organizations or NGOs (Siddiqi and Oever, 1998; Paoletto, 2000). Most of the surveyed international ENGOs (except Greenpeace and ACOPS) are working in different sectors of the environment. Surveyed international ENGOs mentioned that they never give emphasis on the size of the country, population size and political situation to work in developing countries. However Greenpeace representative pointed out that they give emphasis on the economic growth of the country to start work there. As a result Greenpeace is working in Thailand, China and India but not in Bangladesh due to the rapid economic growth of those countries which has a significant relationship with environmental pollution. Most of the surveyed international ENGOs mentioned that their involvements with the developing countries NGOs depend on the particular environmental issue in which they are already involved. The present study also found that most of research and advocacy based Bangladeshi ENGOs have international partners such as donor agencies , the universities and international ENGOs like IUCN, Winrock, Actionaid and others . International conferences and workshops would be the important pathways to bring the NGOs together (Princen and Finger, 1994). Most of the interviewee Bangladeshi and international ENGOs mentioned that came together by attending international conferences, direct personnel communication, contact by email, mail and telephone (Table 4).

Strong personnel communication is very important to start joint collaboration mentioned by ACOPS representative. He informed that they are working in Western Indian Ocean. But the initiative was taken by the Foreign Minister of one the African countries. She met DG of ACOPS in one of the conferences and then the minister asked that why ACOPS was not working in Indian

Ocean. After that ACOPS has started to work there with the collaboration of the governmental agencies and NGOs.

Table 4. Thematic chart relating to development of relation among international NGOs, Bangladeshi NGOs and Donors

Group of ENGOs	Relation	Mode of contact
I	We believe on international network. So we want to work with foreign NGOs in different countries. We also give emphasis on where the contact is stronger , where expertise is required and the area which we are involve in.	International conferences, Personal communication, email, mail, telephone etc.
II	Bangladeshi NGOs have good relation with international NGOs. Several projects are being implemented jointly by national and international NGOs.	Workshops, International conferences Personal communication, email, mail, telephone.
III	Bangladeshi campaigning NGOs have also relation with some international campaigning NGOs	International conferences, Personal communication, email, mail, telephone

Funding sources of ENGOs in Bangladesh

A large number of Bangladeshi NGOs is dependant on foreign fund (Hashemi, 1996; Alam, 1988; Streeten, 1999; Montomery *et al.*, 1996). Present study found that the grants of the donors and western ENGOs are the basic source of fund for most of the Bangladeshi ENGOs . This study found that most of research based Bangladeshi ENGOs have very good relation with different donor agencies like DFID, CIDA, DANIDA, USAID, UNDP, World Bank and others .

Some of the interviewees stressed that all the ENGOs are not receiving foreign funds which is also supported by Hashemi (1996). Hashemi (1996) found that 84% of the total foreign allocation for the NGOs is going to only 15 large NGOs. This study found that in some cases ENGOs get direct funds to implement the wetland and ecosystem conservation and pollution control programme of the donors. In some other cases they identify specific problem of wetlands area and formulate the project proposal to mitigate the problem and then seek the fund to the donor agencies. Sometime donor agencies identify the problem and call for the bid and international and national ENGOs participate on those. For example USAID called an international bid to implement the wetland management and conservation programme in Hakaluki haor at Sylhet, Bangladesh. The international ENGO Winrock made consortium with three Bangladeshi NGOs named CNRS, BCAS and CARITAS. All these NGOs jointly formulated the project proposal and jointly participate in the biding process and won the bid.

A few surveyed ENGOs urged that the donor agencies are only interested to work with large NGOs. They claimed that they submitted several proposals as per the guideline of the donor agencies but their project proposals were unsuccessful and most of the time no reason was given for the rejection.

On the other hand companying ENGOs BAPA is not interested in seeking foreign or governmental fund. BAPA representative pointed "Member fees are the main funding source of BAPA. We never seek fund from international donors and government because we believe in that case we would be depended on them." BAPA thinks if they depend on such funds they cannot raise their voice freely and they have to negotiate with government and donors on some issues. BAPA also claimed that they never accept the donation from the polluters, encroachers and those who are damaging the environment.

This study observed that BEN (Bangladesh environmental Network) is also a source of funding for ENGOs of Bangladesh. BEN is a platform of non resident Bangladeshis (Islam, 2002). They collect funds from the non-residence Bangladeshis and from this donation BEN helps the ENGOs of Bangladesh to promote their activities. For example BEN directly helps BAPA on monthly basis to maintain their office and some other regular expenditure. BEN directly helped BAPA to organize the first and second International Conferences on Bangladesh Environment named ICBEN, 2000 and 2002, in Dhaka. BEN also helped Ongikar Bangladesh to organize the "International Tipaimukh Dam Conference" at Dhaka in 2005.

Relation of national and local ENGOs in Bangladesh

The present study found a good collaboration between Bangladeshi national and local ENGOs. All the surveyed ENGOs are related with other national and local NGOs. However sometimes ENGOs non cooperation or jealousy affect on their activities. As for instance giving programmes at same time by two organizations fail to attract the attention of public and the governmental attention as well. Some surveyed ENGOs complained against some other ENGOs those who are working in the same field. This observation supports the findings of Raweliffe (1998) who found that NGOs are in direct competition with each other for campaign issues, media attraction and sponsorship.

People and Government's attitude toward the ENGOs in Bangladesh

All the surveyed ENGOs mentioned that people are very cooperative to ENGO activities. They also stated that most of the people are very poor and illiterate. The general mass people of Bangladesh are trying to meet their basic material needs. They, therefore, pay little attention to the environmental amenities (Salequzzaman and Stocker, 2001). More over some of the local elites and influential groups are illegally taking the opportunities over the common resources (like public wetlands and water bodies) and damaging the natural resources by over exploitation. These groups are managing the political leaders and governmental officers by giving bribes (Sobhan and Ahmed, 1980; Clapham, 1985 and Ahmad *et al*., 1994). So, these beneficiary groups have become the major opponent of the ENGOs activities at field level.

Cannon (1996) reported a high tension between NGOs and the government in some health programs in Uganda funded by Oxfam. The scenarios are also more or less similar in Bangladesh. Most of the respondent ENGOs pointed out that the GO-NGO relationship is not always friendly. Most of the surveyed ENGOs stressed that the government officials think that what they are doing to protect the environment and biodiversity is right. The government officials most of the time do not attend the meeting which is organized by the NGOs. They are not interested to share their views with the ENGOs and most of the time they don’t include the ENGOs to implement the development and environmental protection projects.

There are a few exceptions as well. The government seek the help of ENGOs to formulate National Environmental Management Action Plan (NEMAP) and ENGOs took part on that (Rahman, 2002). ENGOs also get cooperation from some of the local field officers to run their projects.

Relation of ENGO with NGO Affairs Bureau, Bangladesh

In 1991, Government of Bangladesh created NGO Affairs Bureau to provide one stop services to NGOs such as registration, project approval, fund disbursement and so on (Haque, 2004).All the NGOs who are working with foreign funds must be enrolled with NGO Affairs Bureau . Most of the respondent ENGOs mentioned that the NGO Affairs Bureau acting both as regulator and promoter. NGOs need permission to operate a project with donor’s fund and they also need permission to disburse the foreign money (Fig. 2).

Responded national ENGOs pointed out that sometime they face problem to get the permission from NGO Affairs Bureau. Sometime there is unnecessary delay to give the permission. Some officials of NGO Affairs Bureau are also corrupt. Whereas, the international ENGOs mentioned that they did not face any problem with NGO Affairs Bureau.

Some of interviewee ENGOs thinks that the monitoring of ENGO Affairs Bureau is essential because some the NGOs (general NGOs) are getting fund from different unknown foreign donors and these NGOs are not enrolled with NGO Affairs Bureau. Government suspect that these types of NGOs spending the money in politics and terrorist activities. However, the present study did not find the political affiliations of ENGOs.

On the other hand ENGOs which are only dependant on local funds must be enrolled with Social Welfare Department (Fig 3).

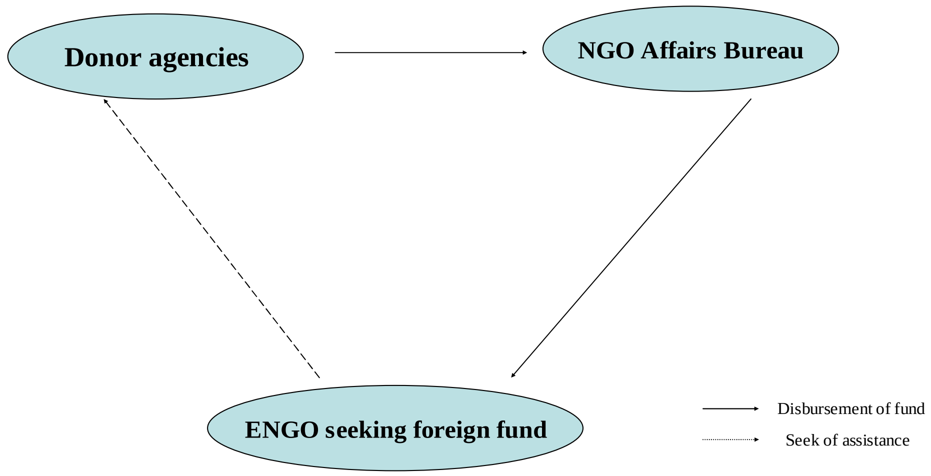


Fig.2. Route of receiving foreign funds for a Bangladeshi ENGO

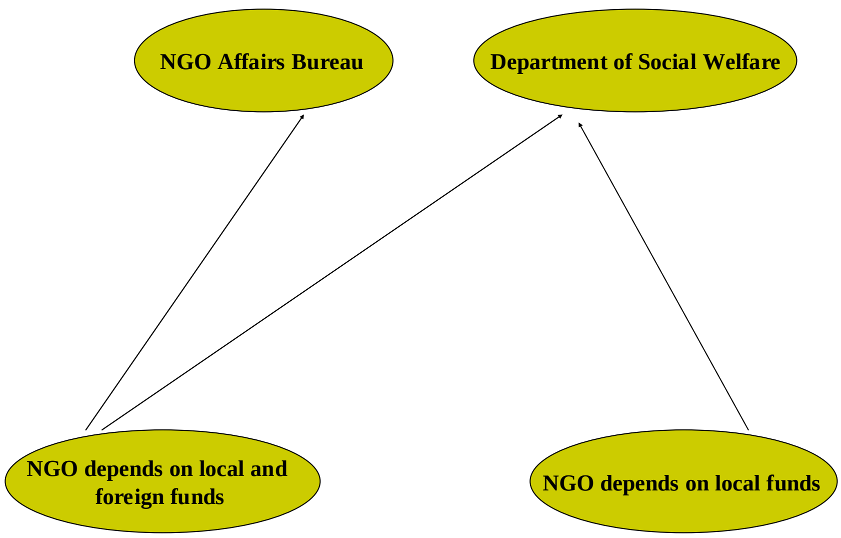


Fig.3.Registration process of a NGO in Bangladesh

Environmental problems of Bangladesh

The surveyed Bangladeshi ENGOs mentioned that air pollution at Dhaka city , ground water contamination with arsenic, agricultural soil contamination with arsenic rich irrigated ground water, surface water pollution with industrial discharges, encroachment of rivers and wetlands, improper disposal of industrial, medical, and household waste, deforestation, loss of open space, loss of bio-diversity, and noise pollution are very common in Bangladesh. But wetland ecosystem disruptions and arsenic pollution is the two major environmental problems all over country. Representatives of international ENGOs (IUCN and IIED) also agreed with this. They mentioned that water pollution with industrial discharge and noise pollution are the problems with some urban areas but wetland encroachment and arsenic pollutions have captured nearly 90% of the country.

Reasons behind losing of wetlands and arsenic contamination

The ENGOs respondents mentioned that the country has not enough natural and mineral resources. The main objective of the government is to provide food and shelter for the people. As a result government's main emphasis is on the industrialization, infrastructural development and urbanization rather than environmental control and wetland protection. People need places for housing so they are filling the wetlands. People are converting wetlands into agricultural lands for cultivation. Wetland and ecosystem conservation legislations are not implementing properly like other legislations in Bangladesh due to corruption, inefficiency and lack of capability of implementing agencies (Lewis, 1992; Islam, 1999; Mahjabeen, 2002). All the respondents Bangladeshi ENGOs and representatives of IIED and IUCN agreed with this. For the example BAPA respondent shared one of their bad experiences with the government officials to implement the wetland protection legislation. BAPA got information that this law was not implemented many places of the country. So BAPA sent the gazette to all the DCs (Deputy Commissioners) and TNOs (Thana Nirbahi Officer) but they responded BAPA "Thank you very much for sending us the gazette but we are unable to take any action as the government did not instruct us to implement this law". So passing of law in parliament and implementation is not same. Government's commitment and strong supervision are mandatory to implement the legislation. On the other hand mass people are illiterate, so they are not aware of their rights. As a result they are not organised and it is easy to misguide them. More over most of people do not know the impact pollution on them and the importance of wetlands and conservation of nature.

The presence of high level of Arsenic (<50 µ/L) in groundwater of Bangladesh has been detected in 1980’s. It is not an anthropogenic reason. The ground rock of Bangladesh is enriched with arsenic. Some scientists claimed that due to withdrawal of excess groundwater for drinking and irrigational purpose, these ground rock is exposed to air. As a result the arsenic is combining with oxygen and coming up with water as arsenate. This arsenate is very dangerous for human-being. According to World Health Organization (WHO), the permissible limit of As in drinking water is 10 µ/L. 80% of groundwater of the country has been contaminated with arsenic. Nearly 90 million Bangladeshi are now at risk from arsenic related several diseases including cancer. The ENGOs representatives mentioned that the economy of Bangladesh is totally depended on agriculture. Paddy culture is the main agricultural sub-sector as rice is the staple food for Bangladeshi. So, arsenic rich ground water is using for irrigation to produce high yield varieties of rice. The presence of arsenic in irrigation water results in significant increase of arsenic concentration in the irrigated soil; particularly in the top layer (up to about 150 mm).Abedin *et al.* (2002) suggested that arsenic can be easily translocated to paddy shoot. Since rice straw is widely used as cattle feed in Bangladesh and India, high arsenic in rice stem and leaf (*i.e.,* in straw) may result in adverse health impacts on cattle and increase human arsenic exposure via the plant-animal-human pathway. Arsenic is also found in several vegetables like potatoes, spinach, brinjal and okra (Alam and Rahman, 2003). So, the whole ecosystem of Bangladesh is now in danger with arsenic contamination.

Role of Department of Environment to protect the environment

DoE is the responsible authority to implement the environmental legislations and monitor the situation at field level. The respondent national ENGOs said that DoE is severely lacking in manpower, budget and logistics and they have no capacity to monitor the situation which is similar to the opinion of Chowdhury (2002) and Islam (2002). DoE have only six offices at six divisional headquarters. There are very few inspectors who are working those offices and it is very difficult for them to monitor the overall environmental situation and implement the environmental laws all over the country. More over involvement of stakeholders with implementation process is very poor.

Achievements of ENGOs in wetland protection and arsenic mitigation programme

This study found that the research based ENGOs are involved with identifying the problems in wetlands conservation by doing active research. They are implementing several projects [*e.g.* MACH (Management of Aquatic Ecosystem through community Husbandry)] project which implementing by BCAS, Caritas, CNRS and Winrock) at field level with the collaboration of donars, international ENGOs, governmental agencies or by themselves. All the national ENGOs are involved to organise workshops, seminars, symposium to disseminate their results and to ascertain new problems. Some of them also arrange training programmes. On the other hand all the surveyed companying ENGOs (eg. BAPA, FEJB, Sundar Jibon) are involved with various activities like demonstrations, organizing press conferences and agitation to draw public attention and to protest governmental and private developmental projects which are damaging the wetlands and environment . They are also acting as pressure groups on the government to implement the environmental rules and regulations. BAPA's representative reported some of their achievements on wetland and river protection issues. One of their important achievements is "Buriganga Bachao Andolon" or "Safe the river Buriganga". Buriganga is the only river of Dhaka city. But unfortunately now Buriganga is nearly a dead river due severe encroachment, industrial pollution and domestic sewage disposal. The businessmen, local influential persons, political leaders and their relatives have already grasped nearly all the bank of the river. They have established industries, shopping centres, apartments and markets. The government is totally reluctant to enforce the wetland and river protection laws here due to strong relations with the encroachers. To prevent this situation, BAPA started its movement named “Buriganga Bachao Andolon”. They arranged several awareness programmes on the issue. BAPA organized boat rally participated by hundreds of boats carrying colourful festoons, banners and placards expressing the demand to demolish the illegal structures from the bank of the river. They also organized seminars, workshops, human chain to aware the people and to create pressure on the law enforcement authority. Media including newspapers and private TV channels also supported the programme by giving huge coverage. At last the government was bound to abolish some of the illegal structures though the action was very inadequate.

Bangladeshi NGOs are also raising their voice against many international developmental programmes which are harmful for wetlands and ecosystem. As for instance one of the respondent NGOs “Ongikar Bangladesh Foundation” organized “International Tipaimukh dam Conference” on 30-31 December, 2005 in Dhaka. The conference was organized to highlight the negative impact of a dam (construing by neighbouring, country India) on wetland and ecosystem of Bangladesh. Ongikar Bangladesh Foundation claimed that after the conference the government of Bangladesh requested them to submit the supporting documents so that the government can start dialogue with India.

NGOs are also implementing several governmental projects as the partners of the government (Islam, 2002). In Tanguar haor (one of the biggest wetland of Bangladesh and a Ramser site) a big project on wetland conservation is going on which is funded by USAID. An international NGOs Winrock is implementing the project with its local partner BCAS, CNRS and CARITAS Bangladesh with the assistance of the government. So Bangladeshi ENGOs are not only acting as pressure group but also helping the government by providing information and technical supports.

Several NGOs like Sunder Jibon, BCAS are doing arsenic related research .They are also arranging seminars and workshops to aware the people about the arsenic problem. Ongikar Bangladesh Foundation took part in marking the arsenic contaminated tube-well in several village for Bangladesh.

Drawbacks of environmental NGOs of Bangladesh

There are severe lack of transparency and accountability in the government but unfortunately all of the Bangladeshi NGOs are also not free from this allegation. This study found that some ENGOs are one man based. Some representatives of surveyed ENGOs are also agreed with this. There is a chairman or executive director who is capable but they have no other capable staff. In fact the chairman or executive director never wants to create second man so they appoint their relatives and dependents as staff. They consider NGO as their business organizations (Islam, 2002). Some surveyed ENGOs urged to verify how the NGO officials are getting so high salaries, big houses and vehicles. There is another allegation that well funded NGOs are also slightly focusing on there target rather than maintenance though they are receiving more fund.

CONCLUSION

The research outcomes demonstrate that ENGOs are playing active role in the environment sector of Bangladesh by doing research, advocacy and companying activities. Bangladeshi ENGOs have very good relations with international ENGOs and donor agencies. Most of the ENGOs (research based) are dependent on the foreign aids. But the prominent companying ENGOs are not interested to seek governmental and donors supports to uphold their independence and to raise their voice against environmental damage.

The government has passed number of environmental legislations but still the overall environmental condition is deteriorating due to lack of proper implementation activities. MoEF and its daughter organisation DoE are comparatively weak in power in comparison to other ministries. Moreover DoE has no supervision power on the administrative officers like DC (Deputy

Commissioner), magistrate and police who are the major law enforcement authorities at field level. The government is also reluctant to involve the stakeholders in the implementing process. More over government officials are not well aware with the international and national environmental legislations. Poverty, high level of population growth and illiteracy of mass people are also deteriorating the overall condition.

The research outcomes also reveal that campaigners are using a combination of dual tactics to drive campaigns. Activities such as article writing in newspapers, organizing of seminars, workshops, conferences, ministerial meetings and provision of scientific information could be easily classifies as “insider” while demonstrations, rally, agitation, symbolic starvation, are clearly “outsider” or confrontational tactics. They are also going to court against government and private organisations to prevent implementation of development projects which are damaging the nature.

Bangladeshi ENGOs are not involved with business like other general NGOs in Bangladesh. But there are some ENGOs which are basically trying to attract donors and governmental funds just for their own development. The present study also found that some big international ENGOs like Winrock, and IUCN are working in Bangladesh by signing memorandum of understanding with the government as a result they are not enrolled themselves with the NGO Affairs Bureau. There are some problems with the governmental agencies but the national ENGOs may face those problems instead of the international one. So international ENGOs can easily work in Bangladesh and the overall environment is favourable to them. The research based local ENGOs think that they need donor’s supports to conduct their researches and to implement projects at field level whereas campaigning ENGOs specially BAPA think that funds of foreign donors and the government restrict the voice of the ENGOs and destroy their independence.

Virtually it is not possible to protect all the wetlands due to huge population pressure in Bangladesh. So, government should identify some important wetlands and which must be protected from human interventions. Wetlands around the big cities must be preserved. Special training programmes need to be arranged for the law enforcing officers so that they can understand the importance to protect environment and biodiversity. The international and national ENGOs may provide such trainings. Stakeholder's involvement in policy making and implementation process is very essential. More over strong commitment of the government to prevent environmental pollution and protect wetlands is very important. It is also necessary to invent rice which needs low amount of water. People should use surface water because surface water is not contaminated with arsenic.

This study also stressed on the necessity of further studies to ascertain the views of policy makers, law enforcing agencies, stakeholders, donor agencies and mass people in relation with the activities of ENGOs in Bangladesh. ENGOs are also implementing some projects like arsenic mitigation programme, wetlands and biodiversity management projects with collaboration of the government and donors. Future studies also needed to explore the utility and sustainability of those projects.

REFERENCES

Abedin, M.J., Malcolm, S., Andy, A.,Cotter-Howells, J., (2002). Arsenic accumulation and metabolism in rice (*Oryza sativa* L.). Environ. Sci. Technol., **36**, 962 -968.

Ahmad, A.K.F., Sarker, A.E.,Ahmad, M.U., (1994). Participatory development, local government and rural realities in Bangladesh: Some preliminary observations. Report of the Bergen-Dhaka administrative development project, University of Dhaka, Dhaka.

Ahmad, M., (2003). An introduction to the non-profit sector in Bangladesh. Allavida, London.

Alam, A.,Rahman, A., (2003). Accumulation of Arsenic in Rice Plant from Arsenic Contaminated Irrigation Water and Effect on Nutrient Content. In: Ahmed, M.F., Ali, M.A. and Adeel, Z. (Eds). Fate of Arsenic in the environment. Proceedings of the International Symposium on Fate of Arsenic in the Environment, ITN Centre, BUET, Dhaka.

Alam, J., **(**1988). Organizing the rural poor and its impact: the experience of selected non-governmental and governmental organizations in Bangladesh. Economic Bulletin for Asia and the Pacific, 39, 33- 42.

Cannon, C., (1996). NGOs and the state: A case study from Uganda. Development in Practice, **6**,109-113.

Carter, N., (2001). The politics of the environment. Cambridge University Press.

Chowdhury, A., (2002). Politics, society and financial sector reform in Bangladesh. International Journal of Social Economics, **29**, 963-88.

Clapham, C., (1985). Third World Politics: An Introduction. Croom Helm, Beckenham.

Ebdon, R.,(1995). NGO expansion and the fight to reach the poor: Gender implications of NGO scaling-up in Bangladesh. Institute of Development Studies Bulletin, **26**, 49–55.

Fruttero, A., Gauri, V., (2005). The strategic choices of NGOs: Location decisions in rural Bangladesh. Journal of Development Studies, **41**, 759–787.

Hashemi, S., (1996). NGO accountability in Bangladesh: Beneficiaries, donors and the state. in: Edward, M. & Hulme, D. (Eds.), Beyond the magic bullet: NGO performance accountability in the post-cold war world. Kumarian Press, USA, pp25-35.

Haque, S. M., (2004). Governance based on partnership with NGOs: implications for development and empowerment in rural Bangladesh. International Review of Administrative Sciences, **70**, 271-290.

Holstein, J.A.,Gubrium, J.F., (1995). The active interview. Qualitative research methods Series 37, Sage Publications, California.

Holloway, I., (1997). Basic concepts of qualitative research. Blackwell Science Ltd., UK.

Huq, E. M., (2002). A compilation of environmental laws of Bangladesh administered by Department of Environment. DoE and BEMP Publication, Dhaka.

Islam, N., (1999). Flood control in Bangladesh: which way now? The Journal of Social Studies, **83**, 1-31.

Islam, N., (2002).The broader significance of the environment movement in Bangladesh. Bangladesh Environment, in*:* Feroz, A.(Ed.). Bangladesh Environment 2002. BAPA , **1**, pp.1-16.

Jamison, A., (1996). The shaping of the global environmental agenda: The role of non-governmental organisations, in Lash, S., Szerszynski, B.,Wynne, B. (Eds). Risk, environmental and modernity, Sage publication, California,pp. 51-59.

Lewis, D. J., (1992). Catalysts for change? NGOs, agricultural technology and the state in Bangladesh. ODI, London.

Mahjabeen, Z., (2002).Enviornmental movement in Bangladesh: Some case studies, in: Feroz, A.(Ed.) Bangladesh Environment 2002. BAPA , 1, pp.26-37.

Montgomery, R.,(1996). Credit for the poor in Bangladesh - the BRAC rural development programme and the government Thana resource development and employment programme .Finance against poverty, 2, 33-39.

Paoletto, G., (2000). Public–private sector partnerships: An overview of cause and effect. Issues and country experiences in Asia and the Pacific. Policy paper series 1, ADB, Manila.

Princen, T.,Finger, M., (1994). Environmental NGOs in world politics. Routledge, London.

Rahman, A., (2002). Role of NGOs in Advocacy: Lessons learnt from Bangladesh and other South Asian countries. Improving policy-livelihood relationships in South Asia, Issue Paper 3.

Raweliffe, P.,(1998). Environmental pressure groups in transition. Manchester University Press, UK.

Ritchie, J.,Spencer, E.,(1994). Qualitative data analysis for applied policy research. Routledge, London.

Salequzzaman, M.,Stocker,L., (2001). The context and prospects for environmental education and environmental careers in Bangladesh. International Journal of Sustainability in Higher Education, 2, 104-126.

Siddiqi, Najma ,Oever, P., (1998). Report on consultative meeting on partnerships: Joining hands with government and non-government development organizations and local communities. Washington, D.C.: Social Development Department, the World Bank.

Sobhan, R.,Ahmed, M., (1980). Public enterprise in an intermediate regime: A Study in the political economy of Bangladesh. Bangladesh Institute of Development Studies, 1, 23-29.

Strauss, L. A., (1987). Qualitative analysis for social scientists. Cambridge University Press.

Streeten, P.,(1999). Globalization and its impact on development co-operation. IDS Bulletin**, 42** 9-15.

CHAPTER 6

(CAPÍTULO 6)

GENERAL CONCLUSION

(CONCLUISIÓN GENERAL)

6. CONCLUSIONES

Las siguientes conclusiones se han obtenido de este estudio

i) Este estudio predice que las áreas que tienen aguas subterráneas con altos niveles de As también registran altos niveles en los suelos agrícolas, debido al riego que se efectúa con estas aguas. Así, los suelos de Faridpur (con aguas subterráneas con elevada contaminación) contienen niveles cuatro veces superiores de As (concentración promedio 33.15 $mg \cdot kg^{-1}$) que el valor promedio establecido para suelos (10 $mg \cdot kg^{-1}$) a escala mundial, y cinco veces superior que las concentraciones de As en los suelos de Dhamrai.

ii) La concentración de otros metales trazas (Cd, Mn, Pb y Se) a excepción de Cu,Ni, Cr, Zn and Co en muestras de suelos en ambas regiones son inferiores a los valores promedios a escala mundial.

iii) El arsénico se encuentra principalmente en la fracción residual en los suelos de ambas zonas (Dhamrai y Fardiphur), lo que indica que éste no es biodisponible, al hallarse en un fracción que forma parte de la matriz mineral.

iv) Los factores “Environmental Risk Factor (ERF)”, “Geo-accumulation index (Igeo)”, y “Metal Pollution Index (MPI)” mostraron que los suelos agrícolas de Dhamarai y Faridpur están libres de polución/contaminación por arsénico y otros metales trazas. No obstante, el factor ERF mostró que estos suelos se hallan polucionados por Cu.

v) Las organizaciones no gubernamentales implicadas en el medio ambiente están desempeñando un papel activo en el sector ambiental en Bangladesh mediante actividades relacionadas con la investigación, consultoría y acciones relacionadas con campañas publicitarias educativas de la ciudadanía. Las ENGOs de Bangladesh mantienen una excelente relación con otras ENGOs internacionales.

vi) La mayoría de las ENGOs son dependiente de ayudas extranjeras. Pero algunas de ellas están buscando sistemas de financiación para sus actividades que le permitan ser independientes de las ayudas gubernamentales o de instituciones extranjeras, y así poder mantener su voz ajena de presiones frente a los daños ambientales.

vii) Las ENGOs de Bangladesh no están implicas en negocios, como ocurre con otras NGOs in Bangladesh. No obstante, algunas ENGOs están en la actualidad orientadas a conseguir fondos para su propio desarrollo. Así algunas ENGOs son unipersonales, de tal manera que su dirección y contabilidad deberían ser ampliamente cuestionadas, y sometidas aun procesos de auditoría externa.